VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

NO. LXXIV.—MARCH, 1875.—VOL. XIII.

SKEW ARCHES.

LOGARITHMIC METHOD.

II.

By E. W. HYDE, C. E.

Written for Van Nostrand's Magazine.

In this method the soffit is cylindrical, as in the last, and the case considered will be that in which the right section is circular.

The heading joints are *planes* parallel to the P F, which, therefore, cut the soffit in ellipses, which are the h j c's. The c j c's are drawn on the soffit in such a manner as to cut each h j c at *right angles.*

Now, the angle between any two lines of the soffit remains unchanged after the development; hence, the developed c j c's must cut the developed h j c's at right angles. Also, if two lines be perpendicular to each other, their projections on a plane parallel to one of them will be perpendicular; hence, if the arch be projected upon a plane parallel to the P F, the vertical projections of the c j c's will cut the ellipses which are the vertical projections of the h j c's at right angles. These principles will be used in obtaining the equations of the curves.

Let A B B_2 A_2 » B′ V′ A_2 be the projections of the Ex. S., and C D D_2 C_2 » D′ V C_2 those of the soffit. O Q is the axis of the cylinder, D C_1 C_2 D_2 is the development of the soffit to be constructed from the projections, or by means of ordinates found from equations (1) or (2).

The developed h j c's are all parallel to D E O, F C_1, and hence may be drawn from a pattern constructed by means of this curve. Divide D D_2 into such a number of equal parts as will make the voussoirs of convenient size, and draw the h j c's through the points of division by the pattern. The length of one of these curves is equal to that of a semi-ellipse cut from the soffit by a P F, and is calculated by the aid of the following formula, obtained by integrating the differential of the elliptical arc.

If S = length of semi-ellipse, a = semi-major axis and e = eccentricity, then

$$(36)\quad S = \pi a\left(1 - \frac{e^2}{4} - \frac{3\,e^4}{64} - \frac{5\,e^6}{768} - \text{etc.}\right)$$

The *middle* h j c, *n o*, must be next divided up into a convenient odd number of equal parts. The division is done on the middle line, in order that the two faces of the arch may be alike. We will next find the equation of the curve k O_2 m of which the c j c's on the development of soffit are portions.

We have already found the equation of D E F C_1, equation (1), in considering the helicoidal method. With the origin at O_1, it is

$$y = -\frac{h}{2}\cos\frac{x}{r}$$

Differentiating

$$(37) \qquad \frac{dy}{dx} = \frac{h}{2r} \sin \frac{x}{r}$$

If $k\,O_2\,m$ cut D E O_1 F C_1 at right angles, we must have, at the point of intersection,

$$1 + \frac{dy}{dx} \cdot \frac{dy'}{dx'} = o, \text{ or } \frac{dy'}{dx'} = -\frac{dx}{dy}$$

in which $\frac{dy'}{dx'}$ is the differential co-efficient of the curve to be found. Substitute the value of $\frac{dx}{dy}$ from equation (37).

$$\therefore \frac{dy'}{dx'} = -\frac{2r}{h \sin \frac{x}{r}}, \text{ or dropping the}$$

primes, since the x and y in both numbers of the equation refer to the same point,

$$dy = -\frac{2r}{h} \cdot \frac{dx}{\sin \frac{x}{r}}.$$

$\therefore$ Integrating

$$(38) \qquad y = -\frac{2r^2}{h} l_e \tan \frac{x}{2r} + c,$$

in which l_e signifies Naperian logarithm.

If we let $y = o$, when $x = \frac{\pi r}{2}$, this being the condition that the curve shall pass through O_2, we have

$$o = -\frac{2r^2}{h} l_e (1) + c;$$

$$\therefore c = o, \text{ and}$$

$$(39) \qquad y = -\frac{2r^2}{h} l_e \tan \frac{x}{2r}.$$

If we move the origin to O_2 by placing $x = x' + \frac{\pi r}{2}$, equation (39) becomes

$$y' = -\frac{2r^2}{h} l_e \tan \left(\frac{x' + \frac{\pi r}{2}}{2r} \right) =$$

$$-\frac{2r^2}{h} l_e \tan \left(\frac{x'}{2r} + \frac{\pi}{4} \right);$$

or dropping primes and reducing

$$(40) \quad y = -\frac{2r^2}{h} l_e \left(\frac{1 + \tan \frac{x}{2r}}{1 - \tan \frac{x}{2r}} \right)$$

In (40) if

$$x \quad o, y = -\frac{2r^2}{h} l_e (1) = o;$$

$$x = \frac{\pi r}{2}, y = -\frac{2r^2}{h} l_e (\infty) = -\infty;$$

$$x = -\frac{\pi r}{2}, y = -\frac{2r^2}{h} l_e (o) = +\infty.$$

$\therefore$ the curve is asymptotic to the right lines

$$x = \pm \frac{\pi r}{2}; \text{ } i.e., \text{ to } l \text{ X and D D'}.$$

If the obliquity of the arch in fig. (2) were in the *opposite direction*, the right hand members of equations (1), (38), (39), and (40) would all be *positive*.

To adapt equation (39) to convenient computation, let $x = n\ \pi\ r$, which is equivalent to dividing the distance $\pi r = O_1 X$ into n equal parts, for which ordinates are to be calculated.

$\therefore$ Substituting common logarithms for Naperian,

$$(41) \; y = -\frac{2r^2}{h} \cdot \frac{1}{M} l_a \tan \frac{n\pi}{2},$$

in which l_a signifies common logarithm, and M is the modulus of the common system. From this equation any number of ordinates may be easily calculated for the construction of the curve $k\,O_2\,m$.

The equation of the curve K O P P_1 will next be found. This is the horizontal projection of the curve on the soffit of which $k\,O_2\,m$ is the development. Its vertical projection is of course the semicircle D' V C_2. It is plain that for any value of y the x for the new equation will bear a certain relation to the x of equation (39), and hence may be derived from it. Call the co-ordinates of K O P x' and y', x and y being those of equation (39),

$\therefore x' = -r\left(1 - \cos \frac{x}{r}\right)$; whence $x =$

$r \cos^{-1}\left(\frac{x' + r}{r}\right)$, and $y' = y$, the origin being at O_1.

Substituting in equation (39) and omitting primes,

$$(42)\quad y = -\frac{2r^2}{h} l_e \tan\tfrac{1}{2}\left[\cos^{-1}\left(\frac{x+r}{r}\right)\right]$$

In (42) change the origin to O, and we have

$$(43)\quad y = -\frac{2r^2}{h} l_e \tan\tfrac{1}{2}\left(\cos^{-1}\frac{x}{r}\right).$$

Now we have by trigonometry

$$\cos^{-1}\frac{x}{r} = \tan^{-1}\frac{\sqrt{1-\frac{x^2}{r^2}}}{\frac{x}{r}} = \tan^{-1}\frac{\sqrt{r^2-x^2}}{x}$$

also $\tan\frac{1}{2}$

$$\left(\left(\tan^{-1}\frac{\sqrt{r^2-x^2}}{x}\right)\right) = \frac{-1+\sqrt{1+\frac{r^2-x^2}{x^2}}}{\frac{\sqrt{r^2-x^2}}{x}} =$$

$$\frac{r-x}{\sqrt{r^2-x^2}} = \sqrt{\frac{r-x}{r+x}}$$

Substituting in (43) we have

$$(44)\; y = \frac{-2r^2}{h} l_e \sqrt{\frac{r-x}{r+x}} = \frac{r^2}{h} l_e\left(\frac{r+x}{r-x}\right),$$

which is the equation of K O P with the origin at O, O Q being the axis of y.

In (44) if $x = o$, $y = \frac{r^2}{h}\, l_e\,(1) = o$

" $x = r$, $y = \frac{r^2}{h}\, l_e(\infty) = \infty$

" $x = -r$, $y = \frac{r^2}{h}\, l_e(o) = -\infty$.

Equation (39) solved for x is:

$$(45)\quad x = 2r\tan^{-1} e - \frac{hy}{2r^2}$$

in which e is the base of the Naperian system of logarithms. It is sometimes desirable to consider y as the independent variable, in which case the equation takes this form.

We will now give a table of values of $\frac{1}{M} l_e \tan\frac{n\pi}{2}$ corresponding to a series of values of n, also the values of x in equation (44) for which the ordinates are equal to the corresponding ordinates of the curve $k\ O_2\ m$.

TABLE III.

Values of n in Equation (41.)	Values of $\frac{1}{M} l_e \tan\frac{n\pi}{2}$.	Values of x in Equation (44) for which y is equal to the y of Equation (44).	REMARKS.
0.01	— 4.2331	0.99951r	*N.B.*—The values of x in column 3 are to be laid off from the *axis* of the *cylinder* as the axis of y. *In equation* (41) *the axis of* y *is* $O_1 D_2$. To obtain the corresponding values of x for the curve I O L M, *substitute* r_1 *for* r in the 3d column, the axis of y being the same.
0.02	— 3.4601	0.99803r	
0.03	— 3.0541	0.99556r	
0.04	— 2.7659	0.99211r	
0.05	— 2.5421	0.98769r	
0.10	— 1.8427	0.95106r	
0.15	— 1.4266	0.89101r	
0.20	— 1.1240	0.80902r	
0.25	— 0.8810	0.70711r	
0.30	— 0.6742	0.58779r	
0.35	— 0.4897	0.45399r	
0.40	— 0.3195	0.30902r	
0.45	— 0.1577	0.15643r	
0.50	— 0.0000	0.00000r	

By means of this table the curves $k\ O_2\ m$ and K O P may be easily and accurately constructed, as well as the curves I O L M and N R O_4 for the Ex s.

For the curve I O L M, which is the intersection of a c j s, with a cylinder concentric with the soffit, we have if x be the abscissa of K O P, x' the abscissa of I O L M and r_1 the radius of the concentric cylinder,

$$\frac{x}{x'} = \frac{r}{r_1},\ \text{or}\ x = \frac{rx'}{r_1}.$$

This value in equation (44) gives

$$(46)\; y = \frac{r^2}{h} l_e\left(\frac{r_1+x}{r_1-x}\right)(\text{primes omitted}).$$

For the curve N R O_4 which is the development of I O L M, calling the abscissa of $k\ O_2\ m$ x, and that of N R O_4 x', we have

$$\frac{x}{x'} = \frac{r}{r_1};\ \therefore x = \frac{rx'}{r_1},$$

which, in equation (40), gives, omitting primes,

$$(47)\quad y = -\frac{2r^2}{h} l_e\left(\frac{1+\tan\frac{x}{2r_1}}{1-\tan\frac{x}{2r_1}}\right)$$

which is the equation of N R O_4 with the origin at O_4. The ordinates for this curve are the same as those for the curve k O_2 m when we give the proper values to x, that is, make $x = n \pi r_1$, and measure it from the line B_1 B_2 as the axis of ordinates.

The curve S V′ T is a projection of the curve K O P P_1 on a plane parallel to the P F, of which p g is the horizontal trace. In constructing an arch by this method it would be desirable to project it on such a plane, and hence this curve would be needed. It cuts at right angles the projection on its plane of any ellipse cut from the soffit by a plane parallel to the P F, and its equation is found by a process similar to that by which equation (39) was obtained. Let g p be the axis of x and O′ V′ the axis of y. The equation of the ellipses to which the curve is to be normal at point of cutting is

(48) $b^2 (x - a_1)^2 + a^2 y^2 = a^2 b^2$

in which a_1 is the variable abscissa of the centre. Differentiating

$$\frac{dy}{dx} = -\frac{b^2 (x - a_1)}{a^2 y}$$ or substituting value of a_1 from (48)

$$\frac{dy}{dx} = \frac{b\sqrt{b^2 - y^2}}{ay}.$$

This in the formula $1 + \frac{dy}{dx} \cdot \frac{dy'}{dx'} = o$,

gives $\frac{dy'}{dx'} = -\frac{ay}{b\sqrt{b^2 - y^2}}$; or, dropping primes, since x and y in the two members refer to the same point,

$$dx = -\frac{b}{a} y^{-1}\, dy\, \sqrt{b^2 - y^2}.$$

Whence, by integration

$$x = \frac{b}{a}\left\{ b\, l_e \sqrt{\frac{b + \sqrt{b^2 - y^2}}{b - \sqrt{b^2 - y^2}}} - \sqrt{b^2 - y^2} \right\} + c$$

If we let $x = o$ where $y = b$—*i. e.*, place the centre of the curve at O′—then $c = o$, and

(49)

$$x = \frac{b}{a}\left\{ b\, l_e \sqrt{\frac{b + \sqrt{b^2 - y^2}}{b - \sqrt{b^2 - y^2}}} - \sqrt{b^2 - y^2} \right\}$$

This curve is symmetrical about both axes of reference, and is asymptotic to the axis of x.

To obtain (49) in a convenient form for computation, place $y = n\, b$, then

$$(50)\ x = \frac{b^2}{a}\left\{ l_e \sqrt{\frac{1 + \sqrt{1 - n^2}}{1 - \sqrt{1 - n^2}}} - \sqrt{1 - n^2} \right\}$$

From this equation have been calculated the values of the parenthesis for a series of values of n, as given in the following table.

TABLE IV.

Values of n.	Values of $\frac{a\,x}{b^2}$.
0.1	± 2.000
0.2	± 1.313
0.3	± 0.921
0.4	± 0.650
0.5	± 0.450
0.6	± 0.299
0.7	± 0.184
0.8	± 0.093
0.9	± 0.032
1.0	0.000

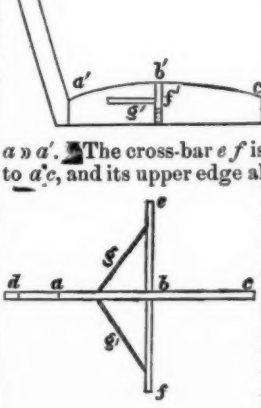
The c j c's on the development of the soffit may be constructed by means of a pattern, one side of which is cut by the curve k O_2 m, and the other side is straight and parallel to l X. By placing this pattern upon the curve k O_2 m, laying a straight-edge along the back, and then sliding the pattern till it passes through the different points of division on the line n o, the proper portion of the pattern for each curve will be found. For construction upon a very large scale —as, for instance, upon a platform the true size of the arch—this method would be impracticable. The point of the curve k O_2 m which passes through any point of division on the curve n o may then be found by calculation. Find by measurement computation the value of x for the point of division—*i. e.*, its distance from the line D D_2; take this distance as a fractional part of πr—*i. e.*, as a value of n—and, substituting in equation (41), find the corresponding value of y; this will be the constant c of equation (38). Subtracting this from the ordinates found from Table III. will give the ordinates of the curve measured from a line parallel to O_1 X through the point of

division. It would also be desirable to determine the exact point in which any c j c cut the curve $D_2 C_2$. We can approximate very closely to this as follows: Find the point as nearly as possible by sketching in the curve from Table III.; through the point thus found draw a parallel to $O_1 X$; find the distance from this parallel to the one drawn through the point of division on *n o* corresponding to the same c j c; add this distance to the value of *c* found as above; take this as the value of *y* in equation (45), and compute from it the corresponding value of *x*; this will be the true abscissa of the curve on the line parallel to $O_1 X$ through the point as first found, and of course will give the intersection of the c j c with the curve $D_2 C_2$ with great accuracy.

The h j s's are, of course, planes parallel to the P F. The c j s's are a species of conoid generated by a right line moving on the axis of the cylinder as one directrix, a c j c as another, and remaining always perpendicular to the former. Any plane perpendicular to the axis is therefore a plane directer. The intersection of any c j s with the P F will be a curve, several points of which will be needed in a construction upon a large scale. These may easily be found by drawing one or more semicircles between $D'V'C_2$ and $B'V'A_2$, finding, by Table III., the curves corresponding to I O L M, for the cylinders of which these semicircles are the vertical projections, and then erecting perpendiculars to the ground line from the points of intersection of these curves with the P F (or planes parallel to it) to meet the semicircles. Projected on a plane parallel to the P F, these curves of intersection of the c j s's with the P F will be normal to the elliptical section cut from the soffit by the P F at the points in which they cut it, and hence will be tangent to the projections on the same plane of the c j c's. All the above remarks apply also to the intersection of a c j s with any h j s—*i. e.*, any plane parallel to the P F.

In order to cut the voussoirs patterns must be made of the cylindrical and plane faces of each. It will also facilitate the operation to construct each in isometric projection, drawing on the cylindrical face one or more elements of the cylinder as guides in the cutting. Cut first the two plane faces of the voussoir precisely parallel to each other; cut roughly another plane face, making an angle with these two approximately equal to that between the P F and a tangent plane to the soffit at some point of the cylindrical face of the voussoir (*i. e.*, to the angle B of equation (51), from which equation its value may be found); lay the stone in such a position that the first two faces shall be vertical, and the third uppermost; apply to the vertical faces the patterns for the ends of the voussoir, with the edges next the soffit uppermost, their relative position being fixed by measurement from the drawings; mark out the ends by the patterns, and also the points where one or more elements of the cylinder pierces the h j s; sink drafts in the upper face connecting these points, and then cut the cylindrical face by a templet cut to the radius of the soffit, and applied at right angles to the elements. Next apply the pattern of the soffit, and draw by it the lines *a b*, *c d*, for the edges of the stone. In the figure *a d* is an element of the cylinder, the stone being seen from above, and being taken from a course near the crown of the arch.

The warped faces can be cut by means of a templet of the form shown in the accompanying figure. The arc *a b c* » *a' b' c'* is cut to the radius of the cylinder, and the arm *a d* » *a' d'* is firmly fixed so as to be normal to the arc at the point *a* » *a'*. The cross-bar *e f* is perpendicular to *a' c*, and its upper edge also perpendicular to the plane of *a b c* » *a' b' c'* and *a d* » *a' d'*. *g* » *g'* and *g g'* are braces. Suppose the stone were cut, then, if the curved edge of the templet



were applied to the cylindrical face with the edge of cross-bar $e\ z$ coinciding with an element of the cylinder, and the point a » a' at the edge of the voussoir, the edge $a\ d$ » $a'\ d'$ of the normal arm would lie upon the warped face, and coincide with an element of it. If a number of drafts be sunk in the stone, then, by means of this templet, the warped faces can be easily cut. It only remains to cut the Ex s of the voussoir. If this surface is to be a cylinder concentric with the soffit, the intersections of this cylinder with the c j s's can be at once laid off on the stone by the aid of the templet. Measure on $a\ d$ » $a'\ d'$ from a'» a' the distance r—r, between soffit and Ex s; mark the point, and, applying the templet as described above, mark on the stone any number of points in the required curve. If the arch is to be built upon with stone, it would be better to cut the Ex s in steps, each stone having one or more horizontal and vertical plane faces when in position in the arch. This would not add to the difficulty of *cutting* the stones, though it would somewhat to that of making the drawings. This way of cutting the stones is shown in the drawing of the arch according to the "cow's horn" method.

The diedral angle at the edge of a voussoir must not be less than a certain limit, otherwise the stone will be deficient in strength at this edge. The limit is usually taken at 60°; hence it follows that a *full centred* arch should not be constructed by this method with a greater obliquity than 60°; but, as the angle between a tangent plane to the soffit and the P F *increases* as the element of contact is taken higher above the springing plane, up to 90° at the crown, it is evident that a *segmental* arch may be built with a greater obliquity than 60°, whose diedral angles will be within the limits. To find the chord of the segment (*i. e.*, the span),

Let α = C, D, D′ = obliquity of arch.

Let β = angle between P F and tangent plane to soffit; *i. e.*, its limiting angle.

Let γ = angle between the tangent plane to soffit and the H P.

Then we have a right-angled spherical triangle, and by spherical trigonometry,

$$\cos\beta = \cos\alpha \sin\gamma$$

$$\text{or } \sin\gamma = \frac{\cos\beta}{\cos\alpha},$$

$$(51)\quad \therefore \text{Span} = \frac{2r\sin\gamma = 2r\cos\beta}{\cos\alpha}$$

If we let $\beta = 60°$, then $\cos\beta = \frac{1}{2}$;

$$\therefore \text{Span} = \frac{r}{\cos\alpha} = r \text{ secant } \alpha.$$

Also $\cos\alpha = \frac{r}{\text{span}}$ from which we can determine the limit of obliquity for a given segment.

If the span = r, then $\cos\alpha = 1$, and $\alpha = o$. Therefore we may give any obliquity to the arch that we please without passing the limit. If $\alpha = 30°$, the limiting span is

$$\text{Span} = \frac{2r}{\sqrt{3}} = 1.1546\,r.$$

The security of the arch constructed after this method will next be considered. In Fig. 2 the curves Q P′ a and Q P_1' b are the vertical projections of the curves cut from the c j s, whose directrices are the axis of the arch, O Q, and the curve K O P_1 by the planes P c and P_1 O_1. These curves will be shown to have maximum points at P P′ and P_1 P′ where they pierce the soffit. h K O L g is the horizontal projection of the curve cut from the same c j s by the horizontal plane $e\ f$, and it will be shown that its tangent at the point of piercing the soffit is perpendicular to the P F. It will likewise be shown that the tangent plane to the c j s at any point of the c j c is perpendicular to the tangent to the elliptical section parallel to the P F at that point. Hence, where it intersects the soffit every c j s is exactly normal to that direction which we have assumed to be the direction of the pressure.

First to obtain the equation of a c j s. Let the line O X be the axis of x, the line Z O Q the axis of z; then let the axis of y be a vertical line through O. Then the equations of the curve K O P P_1 will be

$$(a)\qquad x^2 + y^2 = r^2$$

$$(b)\qquad z = \frac{r^2}{h} l_e\left(\frac{r-x}{r+x}\right).$$

Equation (*b*) is derived from equation (44) by substituting z for y and changing the sign of the right hand number, because the axis O Q in equation (44) was considered as positive from O toward Q, while now it is taken as positive from O toward z.

Let $\frac{h}{r^2} = c$, and solve equation (*b*) for x.

$$\therefore e^{cx} = \frac{r-x}{r+x}; \text{ whence}$$

$$(52) \qquad x = r\,\frac{1-e^{cx}}{1+e^{cx}}$$

For the point x, we have

$$(53) \qquad x_1 = r \cdot \frac{1-e^{cx_1}}{1+e^{cx_1}}$$

Substitute value of x_1 from (53) in (*a*).

$$\therefore y_1^2 = r^2 - r^2 \cdot \frac{1-2e^{cx_1}+e^{2cx_1}}{1+2e^{cx_1}+e^{2cx_1}}$$

$$= r^2\left(\frac{1+2e^{cx_1}+e^{2cx_1}-1+2e^{cx_1}-e^{2cx_1}}{(1+e^{cx_1})^2}\right)$$

$$(54) \qquad \therefore y_1 = \frac{2r\sqrt{e^{cx_1}}}{1+e^{cx_1}}$$

The equation of a line in X Y through the points $(x_1\ y_1)$ and $(x_2\ y_2)$ is

$$(55) \qquad \frac{y-y_2}{x-x_2} = \frac{y_1-y_2}{x_1-x_2}.$$

Since O Q is a directrix of the surface, we shall have

$$(56) \qquad x_2 = y_2 = o$$

$\therefore$ substituting from (53), (54), and (56) in (55)

$$\frac{y}{x} = \frac{2r\sqrt{e^{cx_1}}}{1+e^{cx_1}} \cdot \frac{1+e^{cx_1}}{r(1-e^{cx_1})};$$

or reducing and making z_1 general by dropping the subscript,

$$(57) \qquad \frac{y}{x} = \frac{2e^{\frac{cz}{2}}}{1-e^{cz}} = \frac{2e^{\frac{hz}{r^2}}}{1-e^{\frac{hz}{r^2}}},$$

which is the equation of a c j s.

Intersect this surface by the vertical plane P c d, whose equation is

$$(58) \qquad z = \frac{2r}{h}(a_1 - x),$$

in which $a_1 = $ O c = intercept on X, and $\frac{2r}{h} = tan\ \alpha$.

Substituting value of z from (58) in (57),

$$(59) \qquad \frac{y_1^2}{x} = \frac{2e^{\frac{a_1-z}{r}}}{1-e^{\frac{2(a_1-z)}{r}}} = \frac{2e^u}{1-e^{2u}}$$

if we let $u = \frac{a_1 - x}{r}$.

This is the equation of the curves Q P′ a, Q P$_1$′ b, etc. In (59) if $x = a_1$, $y = \infty$; $\therefore$ the line $x = a_1$ is an asymptote. Also if $x = o$, $y = o$, and if $x = \pm\infty$, $y = o$, and the axis of x is an asymptote.

Differentiating (59)

$$\frac{dy}{dx} = \frac{2(1-e^{2u})\left(e^u + xe_u\left(\frac{du}{dx}\right)\right) + 4e^{2u}x\left(\frac{du}{dx}\right)}{(1-e^{2u})^2}$$

But $\frac{du}{dx} = -\frac{1}{r}$, therefore after reduction

$$(60) \qquad \frac{dy}{dx} = 2e^u\left\{\frac{r-x-(r+x)e^{2u}}{r(1-e^{2u})^2}\right\}$$

For a maximum $\frac{dy}{dx} = o$;

$$\therefore \quad r - x - (r+x)e^{2u} = o.$$

$$(61) \qquad e^{2u} = \frac{r-x}{r+x};$$

This equation gives the values of x for which y is a maximum.

Now eliminate y between equations (59) and (*a*),

$$\therefore \quad x^2 + \frac{4e^{2u}x^2}{(1-e^{2u})^2} = r^2; \text{ whence}$$

$$x^2\left(\frac{1+e^{2u}}{1-e^{2u}}\right)^2 = r^2; \quad \text{therefore solving for } e^{2u},$$

$$(61') \qquad e^{2u} = \frac{r-x}{r+x}.$$

This equation, which gives the x co-ordinate of the point of intersection of the curves Q P′ a, Q P′ b, etc., with the circle D′ V C_2, is identical with (61), which gives x where y is a maximum; therefore the curve whose equations are

$$\begin{cases} y = \dfrac{2\,e^u x}{1-e^{2u}} \\ z = \dfrac{2\,r}{h}(a_1 - x) \end{cases}$$

has its tangent line horizontal at the point of piercing the soffit.

To find the inclination of the tangent at the point where the curve pierces a cylinder concentric with the soffit whose radius is r_1. If the co-ordinates of this point be x_1 y_1 we have by substituting in (61′), u_1 for u, r_1 for r, and x_1 for x,

$$e^{2u_1} = \frac{r_1 - x_1}{r_1 + x_1}; \quad \therefore e^{u_1} = \sqrt{\frac{r_1 - x_1}{r_1 + x_1}}.$$

Substituting these values in (60),

$$\frac{dy_1}{dx_1} = \frac{2}{r}\sqrt{\frac{r_1 - x_1}{r_1 + x_1}}\left\{\frac{r - x_1 - (r + x_1)\dfrac{r_1 - x_1}{r_1 + x_1}}{\left(1 - \dfrac{r_1 - x_1}{r_1 + x_1}\right)^2}\right\}$$

whence by reduction,

$$(62) \quad \frac{dy_1}{dx_1} = \frac{(r - r_1)\sqrt{r_1^2 - x_1^2}}{r\,x_1} = -\frac{\delta y_1}{r\,x_1},$$

if we let $r_1 - r = \delta$.

If we multiply $\dfrac{dy_1}{dx_1}$ by $\cos\alpha$, we obtain the tangent of the angle between the tangent line to the curves c P » Q P′a, O_1 P_1 » Q P_1′b, etc., at the point of piercing the Ex s and the H P. Call this angle t, then

$$(63) \qquad \tan t = -\frac{\delta y_1 \cos\alpha}{r\,x_1}.$$

Suppose $\alpha = 60°$, $\dfrac{\delta}{r} = \dfrac{2}{15}$, then

If $x_1 = r_1 \cos 10°$, $y_1 = r_1 \sin 10°$, and $t = 0°\ 40'\ 20''$
" $x_1 = r_1 \cos 20°$, $y_1 = r_1 \sin 20°$, and $t = 1°\ 23'\ 20''$
" $x_1 = r_1 \cos 30°$, $y_1 = r_1 \sin 30°$, and $t = 2°\ 12'\ 15''$

Intersect the locus of equation (57) by the plane

$$y = b;$$

$$\therefore \quad \frac{b}{x} = \frac{2\,e^{\frac{cz}{2}}}{1 - e^{cz}};$$

$$\therefore \; b\,e^{cz} + 2\,x\,e^{\frac{cz}{2}} - b = 0;$$

solving this for $e^{\frac{cz}{2}}$ as a quadratic,

$$e^{\frac{cz}{2}} = \frac{-x \pm \sqrt{x^2 + b^2}}{b}$$

$$(64) \quad \therefore z = \frac{2}{c}\,l_e\left(\frac{-x \pm \sqrt{x^2 + b^2}}{b}\right).$$

Differentiating and reducing,

$$(65) \quad \frac{dz}{dx} = \frac{2}{\mp\, c\sqrt{x^2 + b^2}} = \frac{2\,r^2}{\mp\, h\sqrt{x^2 + b^2}}$$

When $x = o$, $\dfrac{dz_o}{dx_o} = \mp\dfrac{2r^2}{b\,h} = \mp\dfrac{r}{b}\tan\alpha.$

" $b = r_1$ and $x = o$, $\dfrac{dz_{or_1}}{dx_{or_1}} = \dfrac{2r}{h}\cdot\dfrac{r}{r_1} = \dfrac{r}{r_1}\tan\alpha$

To find the angle at which the locus of (64) pierces a cylinder concentric with the soffit, eliminate y between $y = b$ and $x^2 + y^2 = r_1^2$.

$$\therefore \quad x_1^2 = r_1^2 - b^2.$$

Substitute this value of x in (65),

(66)

$$\therefore \frac{dz_1}{dx_1} = \frac{2\,r^2}{\mp\, h\sqrt{r_1^2 - b^2 + b^2}} = \mp\frac{2\,r}{h}\cdot\frac{r}{r_1} = \frac{r}{r_1}\tan\alpha$$

If $r_1 = r$, $\dfrac{dz_1}{dx_1} = \tan\alpha$. We see therefore that the locus of (64) pierces the soffit at the angle α.—*i. e.*, its tangent is there perpendicular to the P F—and that it pierces any cylinder concentric with the soffit at a constant angle for any given value of α, no matter what value b may have.

The surface is thus seen to differ very essentially from the helicoid previously considered, as regards tendency to sliding on the coursing joints, as is indeed evident from a comparison of the two drawings.

The tangent plane to the c j s at any point of the c j c, as P P′, must contain the element of the surface through the

point and the tangent line at the point to the curve cut out by a horizontal plane through the point; therefore it must be perpendicular to the P F. The tang. of the angle between it and the H P will be equal to

(67) tan 'P Q C, $cosec\ \alpha = tan$ N

if N be the angle between the normal at P P' and a vertical line; but this is also the expression for the tangent of the angle between a vertical line and the tangent line at P P' to the elliptical section of the soffit parallel to the P F; therefore the assumed direction of pressure is normal to the c j s at any point of the c j c. This result might have been predicted from the mode of construction of the c j c's.

The curve cut from a c j s by the plane

$$(68) \qquad z = \frac{h}{2r}(x - a_1)$$

parallel to the P F is always convex towards the springing plane between the soffit and Ex s. Its equation found by substitution in (57) is

$$(69) \quad \frac{y}{x} = \frac{2\, e^{\frac{h^2}{4r^2}(x-a')}}{1 - e^{\frac{h^2}{2r^2}(x-a')}} = \frac{2\, e^{v}}{1 - e^{2v}}$$

if we place $\frac{h^2}{4r^2}(x - a_1) = v$.

By differentiation and reduction we obtain, in the same way in which we found (62),

$$(70) \quad \frac{dy_1}{dx_1} = \frac{y_1}{x_1}\left(\frac{4r^2 + h^2 r_1}{4r^2}\right),$$

which is the tangent of the angle between the tangent line to the locus of (69) at point of piercing the cylinder whose radius is r_1 and the horizontal plane. To obtain the angle between the tangent line to the curve in space whose equations are (68) and (69) and the H P, multiply (70) by $\sin \alpha = \frac{2r}{\sqrt{h^2 + 4r^2}}$

Call this angle t_1, then

$$(71) \quad tan\ t_1 = \frac{y_1}{x_1}\left(\frac{4r^2 + h^2 r_1}{2r^2\sqrt{h^2 + 4r^2}}\right) = \frac{y_1}{x_1} \cdot \frac{r\ sin^2\alpha + r_1 cos^2\alpha}{r\ sin\ \alpha}$$

If $r_1 = r$, which gives the point of piercing the soffit,

$$(72) \quad tan\ t_s = \frac{y_1}{x_1} \cdot \frac{\sqrt{4r^2 + h^2}}{2r} = \frac{y_1}{x_1} cosec\ \alpha,$$

which is identical with equation (67).

If $\frac{r_1}{r} = \frac{17}{15}$, and $\alpha = 60°$, then

when $\frac{y_1}{x_1} = tan\ 10°$, $t_1 = 11° 52' 50''$, $t_s = 11° 30' 30''$

" $\frac{y_1}{x_1} = tan\ 20°$, $t_1 = 23° 28' 16''$, $t_s = 22° 47' 45''$

" $\frac{y_1}{x_1} = tan\ 30°$, $t_1 = 34° 33' 30''$, $t_s = 33° 41' 24''$

The points for which t_1 and t_s are found being on the same radius are of course on different curves, though these curves are so near together that the difference between the angles t_1 and t_s is very nearly the same as the difference between the slope of the tangents to a single curve at the points of piercing the soffit and Ex s.

The function $n = t_1 - t_s$ is found by differentiation to be a maximum when

$$\frac{y_1}{x_1} = \frac{1}{\sqrt{sin^2\alpha + \frac{r_1}{r} cos^2}} = tan\ 44° 32'$$

where α and $\frac{r_1}{r}$ have the values assigned above. The maximum value of the function in this case is $t_1 - t_s = 55' 31''$.

It appears, therefore, that at *no* point on the c j s, between the soffit and the Ex s does the normal to the c j s vary to any extent from the assumed direction of pressure.

Wool waste is, on account of the large proportion of nitrogen it contains (in pure wool this reaches 16 or 17 per cent.), an excellent manure; but there is this disadvantage about it, that it has to lie 3 or 4 years in the ground before it is decomposed. M. Ladureau, of Tourcoing, has sought to obviate this by heating the waste to 120 or 140 C., whereby a reddish, friable, and easily pulverized product is obtained, having a weak smell of chicory and burnt wool. The waste thus treated, being deprived of water, thereby loses from 10 to 15 per cent. of its weight, but sustains no loss of nitrogen, if the operation is carefully done. The product, with a guaranteed proportion of 6 to 8 per cent. nitrogen, is sold at 13 fr. per 100 kilogrammes; and numerous recent trials of it are said to have given very satisfactory results.—*English Mechanic.*

AMERICAN V. ENGLISH BRIDGES.

From "The Engineer."

RECENTLY some slight controversy arose between well-known authorities, on both sides of the Atlantic, with respect to the relative merits of the two methods or systems of bridge construction practised in England and the United States. At the present, and for some time past, there has been a general and gradually increasing tendency on the part of American engineers, not only to replace old, worn-out, incompetent timber bridges by others of iron, but also to erect original structures of the latter material. No doubt necessity as well as freewill has contributed to this result. But, inasmuch as there is no question that the employment of iron in this capacity has now received an acknowledged stimulus in America, it is a fitting opportunity to make a brief comparison between the two methods of bridge building alluded to. Into this comparison iron bridges alone enter. Structures of timber, however skilfully designed and excellently constructed, cannot be regarded in any other light than that of temporary engineering expedients, doomed inevitably in the course of time, either through their own weakness or incapacity to fulfil the increasing duties demanded of them, to be superseded by those of a more stable and permanent character. The employment of timber bridges in the States, or any new country similarly circumstanced, is not only justifiable but commendable. It is true that we, with all the resources of an old and civilized nation at our command, may smile at the idea of a railway bridge over which the train must crawl almost at a snail's pace, but it must be borne in mind that without that bridge the train could not cross the intervening space at all. In one sense, the object, which is to establish communication for goods and passengers from abutment to abutment, is as adequately accomplished as if the bridge allowed of the passage of the "limited mail" or the "Scotch express." It is in every instance the duty of an engineer to effect the desired purpose by the means at his command, and the fewer and the more imperfect those means are, the greater is the credit due to him when his efforts are crowned with success.

To revert, however, to our more immediate subject. One of the points of superiority claimed by American engineers in their bridges is their greater depth; or, more correctly speaking, the greater ratio of the depth to the span. This is incontestable, but while admitting thus much, we do not intend giving our transatlantic brethren more credit than they deserve. A little inquiry will, we think, discover the reason, or partly the reason, why we are only now, as it were, becoming aware of the economy of deep open web or trussed girders, and why they adopted them contemporaneously with the introduction of those structures of iron in their country. The type of girder first and very extensively used by our engineers for railway bridges, was the plate, or solid continuous web, whether in the box, tubular, or single plate form. All girders of this type are shallow in comparison with those of a trussed description, the ratio of depth to span ranging from about one-twelfth to one-sixteenth—in some instances to one-eighteenth. The necessity for adhering to a comparatively shallow depth in the case of solid or continuous web girders arises from the fact that any increase in that dimension is attended with so large a corresponding increase in the weight of the web itself and the accompanying stiffening irons and wrappers, as to practically nullify the advantages arising from the same cause so far as the theoretical strength of the girder is concerned. Moreover, except in large examples, a continuous web must be thicker than required by theory; that is, its sectional area must be in excess of that which is demanded by the strain upon it, which is another reason for the adoption of a minimum depth. Consequently, when a new form of girder was introduced, with the particular merits and the correct proportions of which our engineers were not well acquainted, it is not difficult to understand how, while adopting the new girder, they gave it, and for a long time

continued to give it, the relative proportions and dimensions of its predecessor. Thus, in fact, we find that the majority of the early open web and lattice girders have a ratio of depth to span of about one-twelfth. As the particular features of the trussed girder became more manifest, and the whole design better understood, it was found that an increase in the depth within certain limits was not attended with the practical disadvantages belonging to the solid-sided form. Hence the ratio was increased. On the other hand, the American engineers were always accustomed not only to the trussed form of girder, but to those whose depth is comparatively very large. From one-eighth to one-tenth was a common ratio of depth to span of their large timber railway bridges. In changing the material of these structures they adhered to the same proportions, and, in fact, followed the same line of argument as our own engineers, although it led in their case to a more accurate conclusion. While admitting the economy of deep trussed girders, it must not be assumed that there is no limit to that dimension. Trussed girders must be laterally stiffened with respect to their webs, as well as those of the plate form, and this can be accomplished in long, compressive members only at a sacrifice. Summing up this part of the question, it is probable that the American engineers err as much in the one extreme as we do in the other.

For several reasons, we shall not enter deeply into the much-mooted point whether pins or rivets constitute the better mode of connecting the web and flanges of a trussed girder. As a crushing argument against the use of pins, the advocates for that of rivets invariably adduce the case of the well-known Crumline Viaduct, in which, after some years of traffic, the pin joints became loosened. The pins were then removed, gusset plates placed over the joints, and the whole riveted together. Although it is undeniable that until the advocates for the use of pins can point to a similar instance in which rivet joints have been removed and pins substituted for them, the advantage will always remain with the partisans of the rivets, yet we do not attach quite so much importance to this individual case as many do. It should be borne in mind that this Crumline Viaduct is one of the early examples of the Warren truss, and it is quite possible that the proportions of the pins and eyes may not have been quite correct. Again, the workmanship may not have been quite so good as it ought to have been. Not that this is our opinion, but these assumptions may be made by those who prefer pins to rivets. On the other hand, we know that among the thousand examples of girders in the construction of which rivets are employed, some are undoubtedly of very inferior workmanship and very unskilfully designed. Nevertheless, the substitution of the one method of connection for the other has not taken place, as in the instance brought forward. That pinned girders —if we may use the term in contradistinction to riveted—are put together with greater facility and rapidity in countries in which skilled labor is both expensive and scarce must be admitted, although this advantage has been very much overrated. But there lies all the superiority which the one system can claim over the other. It will be conceded that, no matter how accurate the proportions, how tight fitting the pins, and how excellent the workmanship, there is the possibility of motion among the several parts of a connection so formed. Will not the agents time and use convert this possibility into a certainty? In other words, the connections of a pinned girder depend not so much upon the soundness of the principle adopted as upon the degree of excellence to which the workmanship attains. Will the time ever arrive when we shall hear the Charing Cross bridge rattle as the trains cross over it, owing to the pins loosening?

Another important distinction between the American and English—that is, between the pinned and riveted systems of bridge construction—is that the effect of the former is to concentrate or localize the strains upon certain points of the structure; whereas the tendency of the latter is to distribute them as uniformly as possible over the whole girder. It is quite unnecessary to allude to the obvious superiority both in theory and practice of the latter system. So far as the web is concerned, in moderately long girders, not exceeding 100 ft., particu-

larly if the live load be light, there is an advantage in reducing the number of bars in the web, or what amounts to the same, in employing the Warren instead of the lattice girder. But, on the other hand, the flanges suffer. The comparatively long interval at which the flanges are supported tends to induce a bending strain upon the centre of that part of the flanges between the apices of the triangles, which in many examples which have come under our notice must be very appreciable. It is obvious that since for certain lengths the flanges are of uniform sectional area, those portions in the immediate contiguity of the intersections of the web, or the apices of the triangles, must be more severely strained than those situated in the centre between two apices. When the distance between any two apices is 12 ft. or 15 ft., as frequently occurs, whatever advantage may be gained by the web is undoubtedly lost in the flanges. It is this which puts a limit to the span of Warren girders, independently of the fact that whenever any bending action is induced in any component members of a trussed girder, the very principle of its design is at once entrenched upon. The action of the strains is no longer confined to simple thrusts and pulls in the direction of the length of the several parts, and the economy of the design is seriously impaired. It is quite possible to construct a pair of deep, light, rickety girders, and brace them together so that they will constitute a tolerably stiff and steady structure for a time; but if the quantity of material required for the bracing be taken into account, it will be found that it would have been almost equally economical to build good strong stiff girders in the first place. In this case very light bracing would suffice, and the bridge would be inherently strong. Girders which possess in themselves their proper amount of rigidity, will require, when of certain proportions, bracing to maintain them in form, but rickety girders will require bracing to force them into form. In making comparisons of the cost of bridges constructed on different principles, nothing is more common than to take the girders separately as an example of the whole structure, and neglect the bracing altogether. Obviously this tells enormously in favor of the rickety style of bridge building.

It has been claimed for the pinned girder, that insomuch as it exposes less surface to the weather, so will it suffer less, and consequently be cheaper to paint. Certainly, if one bar of a scantling of 3 in. by $1\frac{1}{4}$ in. be substituted for three bars, each of 3 in. by $\frac{1}{4}$ in., the surface exposed in the one case will be only one third of that in the other. Thus there will be a gain so far as the web may be considered, but the reverse will occur in the flanges. All pinned girders require deep vertical plates in the flanges, which in the riveted girders can be used more advantageously in a horizontal position. Two or more plates riveted together longitudinally present the same surface to exposure as one, neglecting the thickness, but this is not the case with a vertical plate, which is exposed on both surfaces. The question may be well asked, Shall we ever adopt the pinned girder, or will the Americans adopt the riveted girder? In answer to this there is one very significant fact, that the pinned girder is losing ground with our engineers, even when the bridge is designed for a country where that method of connection was much used, and for which it is well adapted. At the present moment there are no less than sixty-four spans of Warren girders being built for a magnificent Indian river bridge, in which pins are discarded and rivets employed for the connection of the web and flanges. Again, the pin has been superseded by the rivet in the suspension principle. The suspending bars in the Albert bridge over the Thames at Chelsea are not connected by pins, but by rivets. This furnishes another proof that the rigid method of connection is far superior to any other which, even theoretically, allows motion between the connecting parts.

Mr. C. Kingsford, of Fulham, England, has presented a process for mixing slacks of various coals, coke, or other carbonaceous materials, with Portland or other hydraulic cements in suitable manner and proportion. Also for treating artificial fuels with coal tar, common pitch, or asphalte.

EUROPEAN RAILWAY CONSTRUCTION SINCE 1850.

From the "Iron Age."

From a statistical statement just published by the English Board of Trade, showing the length of railway constructed in the various States of the world between the years 1850 and 1872, Herapath's *Railway Journal* presents an abstract, from which we compile: Commencing with the

United Kingdom. In 1850 the length constructed amounted to 6,621 miles, increasing in 1855 to 8,280 miles, reaching 10,433 miles in 1860, and 13,289 miles in 1865, when the increase up to 1870 becomes more moderate, being a total of 15,537, and in 1872 reaching a total of 15,814 miles. These figures show the steady growth of the railway system in a country where capital is abundant and joint stock enterprise is unhampered by State interference.

In France the development of railways under the Companies' system is remarkable. In 1850 there were only 1,689 miles constructed by companies, and 209 by the State, after which period the State ceased construction, and the total mileage constructed rose to 3,434 in 1855, advanced to 5,858 in 1860, increased to 8,439 in 1865, and reached 10,847 in 1870; the increase between the two latter periods being greater than that of the United Kingdom. The seven States comprising the present

German Empire have been very progressive in railway construction, and here, with the exception of Prussia, the State since 1860 appears to have gone ahead of the companies, especially during the five years preceding the Franco-German war, in which the State alone constructed nearly 2,000 additional miles of railway, and the companies over 1,000 miles. As might be anticipated, Prussia takes the lead. In 1850 the State possessed but 1,776 miles of railway, 1,190 miles being made by the companies. In 1872 the total mileage of the Prussian railways reached 8,646, and of this 4,733 miles, or over 50 per cent., were in the hands of the companies. The railway mileage of total Germany in 1872 was 12,701, 7,619 of which were State and 5,082 companies' lines. The Prussian thus represents more than two-thirds of the entire railway system of Germany.

Russia, since 1865, has been making some progress in railway extension, and like her neighbor Austria, very wisely gives the preference to companies over State construction, having increased the mileage of companies' lines from 1,773 miles in 1865 to 6,572 miles in 1870, having only 399 miles of State railway in that year, making a total of 6,971 miles of railway, a very small matter for so vast an empire. The returns before us, however, do not include the additional extensions constructed since 1870.

Austria, since 1860, has not been inactive in railway construction, having increased her mileage from 1,788 miles in 1860, to 2,231, in 1865, reaching 3,724 in 1870, while Hungary keeps pace with the empire by making over 1,100 miles of railway between 1860 and 1870.

Spain and Portugal.—In Spain the effects of disruption and civil war are clearly apparent in the fact that within the five years ending in 1870 but 398 miles of railway have been opened, while in the five years preceding 1865 there were 1,791 miles constructed by private companies. Portugal exhibits but little activity in railway making, the country being no doubt an unpromising one in an engineering point of view.

Italy exhibits a striking contrast to Spain in the rapid strides she has made in opening up the country by railways, having advanced the mileage of her completed railways in the ten years ending 1870 from 1,117 to 3,855 miles, while in the last two years ending 1872 the total length constructed by private companies in Italy (including Rome) amounted to 4,087.

In Holland and Belgium, where the State appears desirous of acquiring the ownership of the railways, but few additional lines have been made since 1870, the increased mileage between 1865 and 1872 being nearly equal in both States. The total length constructed in the former State up to 1872 was 1,043 against 560 miles in 1865 and in the latter 2,004 in 1872, against 1,418 miles in 1865.

Miscellaneous.—In the Northern States of Sweden and Norway the total open mileage has increased in the former from 956 miles in 1865 to 1,198 in 1872, and in Norway from 168 miles in 1865 to 307 in 1872. During the same period Switzerland constructed 137 miles of additional railway, making the total length of Swiss railways up to 1872, 913 miles. Denmark shows a total mileage of 540 miles up to 1872, while Turkey had only constructed by companies a total length of 152 miles of railway up to 1870, and the unprogressive kingdom of Greece winds up the list of European railways with a total of 6 miles. According to this return the total length of European railways in 1865, constructed by private companies, amounted to 39,626 miles, and those constructed by the States to 7,013, making a total of 46,639 miles.

In the United States of America the total length of railways constructed was in 1850, 9,022 miles; in 1855 the mileage increased to 18,454; in 1860 it had risen to 30,634. In 1865 it rose to 35,085, and in 1870 it reached the total amount of 53,399 miles, thus in ten years nearly doubling the lines constructed.

THE NARROW GAUGE IN SWITZERLAND.

From "Engineering."

This season has been marked by an event of considerable importance in the dominion of our railways. I allude to the completion and opening of the first Swiss narrow-gauge railway. Here, like in other countries, railways on a narrower gauge than that of our 4 ft. 8½ in. standard, have been vehemently attacked, both by argument and dogmatically, by engineers devoted to established practice; but, on the other hand, the necessity of cheap branch lines, which could be worked with economy, presented itself with so much urgency that the narrow-gauge system became finally a *fait accompli*, and its future development is but a matter of time, required to extend a knowledge of the sound principles upon which such railways are in fact constructed.

The narrow-gauge line from Lausanne (on Lake Geneva) to Echallens, which was opened last June, has but a length of 15 kilometres or, say 9¼ miles, and is built to a gauge of 1 metre. This same gauge—being also that of your new Indian State railways—has been adopted for all the other smaller lines either building or projected in Switzerland, to which I shall refer hereafter.

The following are the characteristic points in connection with the construction and equipment of the Lausanne line. In the first place, this railway has been traced out partly upon the existing country road, presenting thus a very close adaptation of grade to the natural surface, with maximum inclines of 1 in 25, and smallest curves of about three chains radius. The Vignoles rails have been acquired at a low price from the Fell Mont-Cenis line; but their weight of 58 lbs. is on this account considerably in excess of the requirements of the case, as a 40-lb. rail would have been ample. The cross-sleepers of larch wood are 5 ft. long by 6½ in. by 4½ in.; they are placed at distances of 3 ft. 10 in. and 2 ft. apart at the joints. The ballast is laid 6½ ft. wide and 7 in. below the bottom of the ties. The rolling stock of this little line, consisting of two locomotives, twelve passenger carriages, five luggage vans, and twenty-one goods wagons, have likewise been obtained from the liquidation of the Mont-Cenis line; this stock, however, before it could be employed at Lausanne, had to be first delivered of the mid-rail gear, and second, its gauge had to be reduced by 4⅜ in., this being the difference between the former Mont-Cenis gauge and that of one metre. Subsequently the two engines—the first by which the Fell railway was worked—were found wholly defective, and in consequence two small four-wheeled tank engines, weighing eight tons in working trim, were bought at the Creusot works; these lilliputian engines now working the line exclusively.

The total cost of the line, including rolling stock, has been 78,000 francs per kilometre, or say £5,000 per mile. As far then as economy is concerned, this result is

very satisfactory (our railways of the normal gauge have cost on the average four times as much), but the fact that the line was equipped with an old permanent way and rolling stock points clearly out that the present example cannot be considered as a type representing fairly modern narrow-gauge practice.

The second Swiss narrow-gauge enterprise, still more characteristic than the one described, although of smaller extent, is situated almost on the very top of the celebrated Righi, forming as it were but another link in those mighty chains that are to lay the queen of the mountains in irons. The Righi narrow-gauge road is about three miles in length, connecting the Kaltbad station with that of the Scheideck. The gauge is likewise one metre, and the maximum gradients, worked by adhesion, are 1 in 20. The six-wheeled coupled tank engines of 20 tons weight (built at the new Swiss locomotive works) present no peculiar features, with the exception of the boiler, which is wholly cylindrical and constructed on a plan adopted once by Mr. Ramsbottom in some shunting engines. The long open passenger carriages are carried on two four-wheeled bogies and can accommodate 55 passengers, disposed on eleven parallel benches, to which access is gained by an equal number of side doors. Of course this line serves only tourist purposes during the summer months, and will be ready for use next season.

The other narrow-gauge lines, either building or projected in this country, are for their greater portion the property of the Swiss Society for Narrow-Gauge Railways, a company founded two years ago by Dr. Dubs, late President of the Confederation. I hope to be able to forward you, shortly, drawings illustrative of this company's rolling stock, &c., which has been designed with much care, and with the utmost attention to the comfort of the travelling public. For the present I annex a statement of our narrow guage pursuits, which now stands as follows:

	Kilometres.
Lines of one metre gauge opened	15
" " building	93
" " projected	130
Being a total of	238

or about 148 miles of narrow-gauge railways.

A. BRUNNER,
Inspector of Rolling Stock of the Swiss Railways.

HEAT ABSORBED BY EXPANSION.

By H. S. CARHART, A. M., Professor of Physics, Northwestern University.

Written for VAN NOSTRAND'S MAGAZINE.

THE statement is sometimes made that mere expansion, without the performance of external work, such as forcing aside the atmosphere, does not cool the expanding gas. See an article on "The Mechanical Equivalent of the Heat Unit" in the January ECLECTIC; also, Tyndall's "Heat as a Mode of Motion," page 71. The assertion is one not justified certainly by experiment. Let us put it to the test.

We will screw a copper condensing chamber upon the plate of our air-pump and examine its temperature by means of a sensitive thermopile and astatic needle, the movements of the needle being greatly magnified by projecting its image on a screen by means of our Wale & Co's oxy-hydrogen lantern. Let us first assure ourselves that the temperature of the chamber is the same as the face of the pile. This is the case, for the needle stands at zero. The chamber is now quickly exhausted of air, and the face of the pile again applied. Our magnified image of the pointer connected with the needle moves promptly across the screen, showing conclusively that the chamber is perceptibly cooler than before. While the pump was working, the expanding air was sufficiently chilled to lower also the temperature of the copper vessel.

Here the refrigeration cannot be ascribed to *external* work, for we have accomplished that ourselves by working the pump. The air has "expanded into

a vacuum," exactly as the author of the article referred to would have the experiment performed, the vacuum being produced at every stroke in the pump barrel. And yet the air has been cooled.

But let us vary the experiment so as to lessen the probability of error by a difference of procedure. We so arrange our lantern that a strong beam of light passes through a clear glass receiver on the pump plate. Some light is reflected from the sides of the receiver, but the beam does not mark its way through the interior. In order to insure the presence of a sufficient quantity of vapor of water we will place a beaker of warm water under the receiver for a few seconds. The apparatus being now all arranged, let the attention be directed to the receiver, while we work the pump. The first *quarter of a stroke* is followed by the sudden appearance of a white shaft of light tracking its way through the receiver. Watch the curling cloud, for this it is, as it settles down. Gradually it disappears, but another quarter of a stroke is sufficient to reproduce the beautiful effect. Every minute globule of water reflects to us its quota of light, and by placing our eye in the proper position we discover that the shaft of light is even adorned with the colors of the rainbow. How shall we account for the formation of this cloud except that by expansion the air has been cooled and a part of the vapor of water has in consequence been condensed? Yet no external work has been done in pushing back the outside air, for we have again accomplished that by muscular force.

But if expansion produces cold, clearly heat has been absorbed in doing some kind of internal work, since by the conditions of the experiment it has not been allowed to do external work. What is this internal work? When the air expands its molecules are set in motion, and *some* force must be expended in overcoming their inertia. The force that is called upon to perform this work is evidently the repulsion between the molecules of air. But repulsion in this case owes its existence and intensity to that molecular oscillation which we call heat. Hence, when repulsion does work in setting the particles of air in motion and overcoming their inertia it does so at the expense of the heat of the air, since this is its only base of supplies.

In the *Bulletin* of the Belgian Academy of Sciences (Nos. 9 and 10) M. Melsens communicates a third note on lightning conductors; in this he first shows how a lightning rod, in good condition, and made according to "classical" instructions, failed to completely protect a building fitted with it. The phenomenon seem to point to the inutility of lightning rods with points and multiple conductors. In the second part, he suggests practical means for control and verification of lightning conductors, commending the joint use of a galvanometer, and a Marianini *re-electrometer*, for this purpose. The same number contains an account of observations at Brussels, on the Periseides, in 1874. M. Louis Henry contributes chemical papers on hyponitric anhydride and on acetylenic hydrocarbons. M. Plateau expounds an arithmetical "recreation," and M. Dubois makes morphological remarks on species of *Xanthoura.—English Mechanic.*

Immense Photographs.—There are now on exhibition in Paris, says the *Revue Industrielle*, the two largest photographs which have been made since the introduction of the art. One of these photographs represents the principal facade of the New Opera, the other one of the bronzes—the Departure, by Rude—of the Arc de Triomphe de l'Etoile. Each of these prints measures 4 ft. 3 in. in length and 3 ft. 4 in. in height. They were obtained in one single piece, by well-known processes, and with the aid of a large and specially constructed camera. Except in some of the effects of perspective, which perhaps are not reproduced with absolute fidelity, especially the portion representing the dome of the Grand Opera, which appears, on the photographs, to crown the facade instead of being in a plane further back, all the lines of the pictures are of remarkable excellence; the mouldings, the busts, the medallions, the inscriptions, and even the minutest details being reproduced with rare perfection. The attempt is being made to secure pictures even larger than this.—*English Mechanic.*

ON THE FRICTION OF AIR IN MINES.*

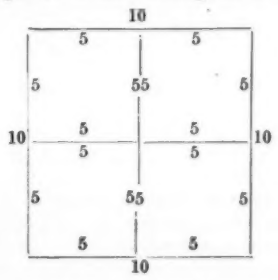
BY J. J. ATKINSON.

(The amount of friction is reckoned as estimated by the amount of the pressure or force required to overcome it.)

NUMEROUS experiments have been made to find out the laws that govern the friction of air and gases, both in pipes having a uniform section, and, to a less extent, in the irregular air-ways of mines. By these experiments, the following laws have been found to hold good in practice:

The pressure required to overcome the friction of air increases and decreases in exactly the same proportion that the area or extent of the rubbing surface exposed to the air increases or decreases; so that when the velocity of the air, and the sectional area of the air-way, remain the same, the pressure required to overcome the friction is proportional to the area or extent of the rubbing surface exposed to it; and hence, if we double or treble the extent of the rubbing surface, we also double or treble the friction, or, what is the same, the force or pressure required to overcome it. The rubbing surface, of course, depends upon the circumference or perimeter of the air-way, and upon its length. The rubbing surface is found by multiplying the perimeter by the length of the air-way, where it has a uniform section. A circular pipe or air-way offers less rubbing surface, for the same length, than any other form or shape of air-way of equal sectional area; because the circumference of a circle is less, in proportion to its area, than the perimeter or any other figure is to its area. A circle whose area is 1 has a circumference of 3.545, or rather more than $3\frac{1}{2}$; the perimeter of a square is 4, when its area is 1; so that about 7 yards of square pipe would offer the same resistance as 8 yards of round pipe, having an equal size or area of section, when the same quantity of air passes through them in a given time.

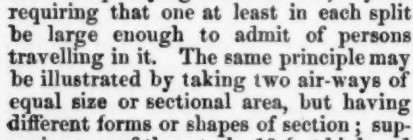
It is true that the friction of air or gas, in passing through the same pipe or air-way, varies in just the same degree that the density of the air or gas may vary; but in air-ways in coal mines the air has always nearly one and the same density, and it is only in particular calculations that it becomes requisite to notice its changes of density, in reference at least to this part of the general subject, since they are so small in amount. This is the case as regards friction, but the effects of variations in the density of the air circulating in mines are more sensible in producing pressure, operating either in favor of or against the ventilating pressure, in rise or dip workings; but these effects belong more especially to another part of the subject. In an air-way 5 feet square, the perimeter of a section is $4 \times 5 = 20$ feet; and if it is 1,000 long, the rubbing surface is $20 \times 1{,}000 = 20{,}000$ square feet. In an air-way 10 feet square, the perimeter of the section is $4 \times 10 = 40$ feet; and if it was 1,000 long, the rubbing surface would be $40 \times 1{,}000 = 40{,}000$ feet; so that, on comparing the two cases, it will be apparent that for four times the area there is only two times the extent of rubbing surface. If such an air-way as that last mentioned (10 feet square, and having a rubbing surface of 40,000 square feet for every 1,000 feet in length) were divided into four equal-sized square air-ways, the rubbing surface exposed to the moving air would be



exactly double by the division; and there would be 20 feet of perimeter for each of the four air-ways, or 80 feet on the whole; so that for a length of 1,000 feet the rubbing surface for the four small air-ways would be 80,000 square feet, or exactly twice as great as that for the one large air-way, although the united areas of the smaller air-ways would be exactly equal

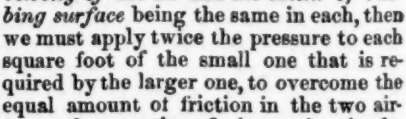
* An Essay read before the Manchester Geological Society, by J. J. Atkinson, Government Inspector of Mines.

to that of the single large one. In one case there would be a single air-way 100 feet in area, and in the other four smaller air-ways, each 25 feet area; but the rubbing surface, and therefore the friction and the pressure required to overcome it for the same gross quantity of air, would be twice as great in the four small as in the one large air-way having the same area. And from this fact we learn that one large air-way is preferable to a number of smaller ones, even if they together make up the same sectional area or size. In practice it often happens, however, that a number of small air-ways can be made and maintained at less cost than one large air-way presenting an equal sectional area; and, in such cases, a few extra air-ways of small area may more than compensate in utility and make up in cost for the absence of one extra-sized air-way; and hence the futility of insisting upon the sectional area of air-ways in mines being of any particular amount, without specifying their number, beyond requiring that one at least in each split be large enough to admit of persons travelling in it. The same principle may be illustrated by taking two air-ways of equal size or sectional area, but having different forms or shapes of section; supposing one of them to be 10 feet high and 10 feet wide, its size or area of section would be $10 \times 10 = 100$ feet; and supposing the other air-way to be 20 feet wide, but only 5 feet high, the area would be the same (or 5×20), 100 feet.



The air-way 10 feet square would have a perimeter of section $4 \times 10 = 40$ feet, while the other would have a perimeter of $(20 + 20 + 5 + 5)$ 50 feet, compared with only 40 in the former; so that for equal lengths the friction of the air would only be 40 in the square air-way compared with 50 in the oblong one; and the friction in 50 yards of length in the square-shaped air-way would be no more than that in 40 yards of length in the oblong one for the same quantity of air. Since the air in a mine presses with nearly the same force upon every square foot, it is quite natural that the frictional resistance should be greater or less in amount, to the same extent that the rubbing surface or number of square feet exposed to the air is greater or less; and this is the general law or principle that has just been stated and illustrated by examples.

The pressures employed to ventilate mines are commonly reckoned at so much per square foot of area, and not by the entire pressure employed, which is equal to the number of square feet multiplied by the pressure on each square foot of sectional area in the shaft or air-way. For instance, a ventilating pressure of 10 lbs. to the square foot on an air-way 100 feet in area is equal, on the whole, to $10 \times 100 = 1{,}000$ lbs. If the same pressure of 10 lbs. per foot is applied to an air-way of only 50 feet area, the total pressure is only $10 \times 50 = 500$ lbs.; owing to the area being one-half, the total or gross pressure is also only one-half. In order to get the same total pressure, we must make the pressure per foot greater in the same proportion that the area is less, when the rubbing surface and *velocity* of the air are to be the same in two cases. If we reckoned ventilating pressure by its total amount, we would not require to notice this law, it is so self-evident; and it is only because we speak and treat of it as so much pressure per *square foot* that we require to consider the number of square feet to which it is applied. If there were two air-ways, one just twice the area of the other, the *velocity of the air* and *the extent of rubbing surface* being the same in each, then we must apply twice the pressure to each square foot of the small one that is required by the larger one, to overcome the equal amount of friction in the two air-ways, the quantity of air passing in the smaller one being just one-half of that in the larger. As an example, if we had an



air-way 10 feet by 10 feet the area would be 100 feet, and the perimeter of section

40 feet; and another air-way 5 feet high by 15 feet wide, the area would be 75 square feet, or just 3-4ths of the area of the former; the perimeter of section would be, however, exactly 40 feet in both air-ways. In the larger air-way we would only require to employ 3-4ths of the pressure on each foot of surface (that is to say, 3-4ths of the water gauge) that we would require to employ on each foot of the smaller area, so as to make up the same total ventilating pressure—the rubbing surface for an equal length of air-way being the same in the two cases, because the perimeter of their sections are equal, and the velocity of the air being taken as the same in the two cases, the quantities of air per minute would be simply proportional to their respective areas under these circumstances.

This second law relating to the friction of air in mines need not have been noticed at all if we had reckoned ventilating pressure as a whole; but as we generally speak of it as so many pounds per foot, we must also take into account, as has previously been remarked, the number of square feet to which it is applied—that is, the area of the section of the air-way—in the same manner that the area in inches of the cylinder or piston of a steam engine multiplied by the pressure on each square inch gives the total force applied to the piston. An inch of water-column, as shown by a water-gauge, represents a pressure of about 5.2 lbs. per square foot.

The third general law relating to the friction of air in mines is, that the pressure required to overcome the friction in the same air-ways *varies* (that is to say, increases or decreases) in the same proportions that the *square* of the velocity of the air increases or decreases; so that a double velocity of air, in the same air-way, meets with a *double double*, or four-fold resistance; a treble velocity meets with a *treble treble*, or nine-fold resistance; and a velocity of four times as great gives rise to a resistance four times four, or sixteen times as great. In the same way a half velocity meets with one-half of a half, or 1-4th of the resistance; 1-3d of the velocity encounters only a third part of a third, or 1-9th of the friction, and so on.

The third law of friction, at first sight, looks rather complex. Consideration, however, shows it to be quite natural, because, if we double the velocity of the air in the same air-way, we, in the first place, cause twice the quantity of air to meet the resistance in a given time; and, in addition to this, every part of this double quantity meets every resistance with a double velocity or momentum; the double quantity of air, and the double velocity taken together, may well be supposed to give rise to a *double double*, or four-fold resistance; and this is the true law. Again, if we treble the velocity of the air, we thereby cause three times the number of particles to meet the resistance in each moment of time, and this alone should treble the resistances; but, in addition to this, the treble quantity meets the resistances with three times the speed or momentum, which *trebles the threefold* resistance that arises from the threefold number of particles of air that meet the resistances each moment of time; on the whole making a ninefold resistance for a threefold quantity of air in a given time.

The laws of ventilation would be very simple, quite as simple, indeed, as they are natural, were it not that, in lieu of the mere quantity of air circulating in a given time, or the mere velocity of the air, we must make use of the square of the quantity, or, what is the same, the square of the velocity, in our calculations; and, as a matter of course, in calculations for comparative results, if we employ the squares of the quantities or velocities, we must expect, as results, not the quantities or the velocities simply, but their squares, and therefore it will be necessary to extract the square roots of the results so obtained in order to get at the simple quantities themselves.

It has already been stated that there is one other principle bearing on the friction of air passing through mines, to the effect that it is greater or less in the same proportion that the density or weight of each cubic foot of air is greater or less; so that if each cubic foot of air had a double weight it would have a double amount of friction; or, if it had only half the weight, it would have only half the amount of friction in the same air-way, when the velocity or the number of cubic feet per minute is the same; but the variations in the density of the air in mines are so very small, compared with

the whole density, that the effects of this law on the amount of ventilation are very small—so small, indeed, as to be practically unfelt, at any rate as an increase or reduction of friction in the moving air; even in an upright or vertical shaft the density of the air would only be altered, on the average, by about 1-60th part of its amount, compared with a level air-way, supposing the shaft to be 150 fathoms deep, so far as the pressure of the atmosphere is concerned. The changes of density arising from the heat of upcast shafts, in expanding the air, have a greater effect, so far as such shafts alone are concerned, under furnace ventilation; but this does not affect the friction of the air in the workings of the mine; and, even in these shafts, the lessened density, arising from expansion by heat, has its effects on reducing the shaft friction greatly modified, by the greater velocity due to the increase in the volume of the air; this increased velocity does more than make up, by the accompanying increase of friction, for any reduction in such friction that is due to the lessened density of the air in every case; the friction, in fact, increases or decreases in just the same proportion that the volume of a given weight of air increases or decreases, whether the change of density arises from change of temperature or from change of pressure. Supposing the temperature of the air in a mine to be 60° in winter and 65° in summer, on the average, such a change would only alter the friction in such mine by about 1-104th of its amount. In summer the friction would be 1-104th greater than in winter for the same weight of air, but it would, at the same time, be about 1-104th part less for the same volume of air—an alteration hardly worth notice for the present purpose. The total friction or the total pressure due to the friction of air rubbing against the top, bottom, and sides of the air-ways of mines is not very well ascertained; and all the experiments, at least all that have come under my notice as having been made for the purpose, have been in some respects of a rude character, the necessary particulars not being given in the accounts published to fix with rigid accuracy its amount.

From the best accounts of such trials, it seems probable that for every foot of rubbing surface, and for a velocity in the air of 1,000 feet per minute, the friction is equal to 0.26881 feet of air column of the same density as the flowing air, which is equal to a pressure, with air at 32°, of 0.0217 lbs. per square foot of area of section; calling this the *co-efficient of friction*, we have the following rules with respect to the friction of air in mines:

Total pressure..... $pa = ksv^2$	(1)	Where p = pressure per sq. foot, a = sq. feet of sectional area.
Rubbing surface..... $s = \frac{pa}{kv^2}$	(2)	s = the area of rubbing surface exposed to the air.
Velocity squared..... $v^2 = \frac{pa}{ks}$	(3)	v = the velocity of the air in thousands of feet per minute—1,000 feet per minute being taken as the unit of velocity.
Co-efficient of friction..... $k = \frac{pa}{sv^2}$	(4)	
Pressure per foot..... $p = \frac{ksv^2}{a}$	(5)	
Area of section..... $a = \frac{ksv^2}{p}$	(6)	k = the co-efficient of friction in the same terms or unit as p is taken in.

Putting these formulæ into words, we have the following set of rules:

(1.) *To find the total pressure* due to friction.*—Multiply the co-efficient of friction by the extent of the rubbing surface, and the product by the square of the velocity in thousands of feet per minute; that is to say, by the square of the quotient resulting from dividing the velocity in feet per minute by 1,000.

(2.) *To find the rubbing surface.*—Di-

* The *total pressure*, in these rules, is found by multiplying the sectional area of the air-way, in feet, by the pressure per square foot.

vide the total pressure by the product of the co-efficient of friction and the square of the velocity in thousands of feet per minute.

(3.) *To find the velocity.*—Divide the total pressure by the product of the co-efficient of friction and the rubbing surface; this gives the square of the velocity, the square root of which is the velocity itself, in thousands of feet per minute; this multiplied by 1,000 will give the velocity in feet per minute.

(4.) *To find the co-efficient of friction from experiments.* — Divide the total pressure by the rubbing surface and the square of the velocity (in thousands of feet per minute) multiplied together.

(5.) *To find the pressure on each foot of section.*—Multiply the co-efficient of friction, the rubbing surface, and the square of the velocity (in thousands of feet per minute) all into each other, and divide the product by the area of the section.

(6.) *To find the area of the section.*—Multiply the co-efficient of friction, the rubbing surface, and the square of the velocity (in thousands of feet per minute) all into each other, and divide by the pressure on each foot of sectional area.*

The foregoing rules embrace only the pressure due to friction, and not that due to the creation of velocity, so that they may be regarded as being true of long pipes and air-ways, as they are given, but as requiring an allowance for the pressure due to the velocity in short pipes and air-ways. This allowance renders the rules much less simple.

Now, these rules, which are found out by practical trials or experiments, lead us to many very important conclusions in reference to the best mode of conducting the ventilation of mines, in proof of which it would be easy to multiply examples.

These laws of friction may be illustrated by the following example:

In an air-way 10 feet square = 100 feet area, and 25,000 feet, or nearly five miles long, if the velocity of the air were 1 foot per second, or 60 feet per minute, the quantity of air would be 6,000 feet per minute—the pressure due to friction (taking the pressure at 14.7 lbs. per square inch, and the temperature at 32°) would be .7812 lbs. per square foot of sectional area of the air-way, the horse-power being .142.

In another air-way of equal length, but instead of being 10 feet square only five feet square, giving only 25 feet or 1-4th of the area of the larger air-way, we have the following results: The rubbing surface in the small air-way would only be one-half of that in the large one; but, on the other hand, the area to which the ventilating pressure would apply would only be 1-4th; and at the same time the velocity of an equal volume of air would be increased fourfold in the lesser air-way; this increase of velocity alone making sixteen times the friction, so that on the whole it would be thirty-two times as great; making the pressure on each square foot 24.998 lbs., being thirty-two times as great as in the large air-way. And therefore, on the whole, the *power* expended would be also thirty-two times as great in the small as in the large air-way, for the same amount of ventilation per minute: the coals consumed would also be thirty-two times as great. If furnace ventilation were used, and the heat of the upcast shaft and pressure per foot were the same, instead of 6,000 cubic feet per minute, as in the large air-way, we should only have 1,061 feet in the smaller one; but, in this case, the coals burnt would only be $\frac{1}{\sqrt{32}}$, or between 1-5th and 1-6th of the former quantity, and the power would be less in the same proportion, for the lesser quantity of air. This shows in a striking manner the great advantage of large air-ways.

The calculations relative to the two cases, compared with each other for the example just given, stand thus:

FOR THE LARGE AIR-WAY.

The length is 25,000 feet, and the perimeter of section is $4 \times 10 = 40$ feet; so that the rubbing surface

$$s = 40 \times 25{,}000 = 1{,}000{,}000 \text{ sq. ft.}$$

the area $a = 10 \times 10 = 100$ square feet,

the velocity $v = \frac{60}{1{,}000} = .06$, in thousands of feet per min.;

* If it is preferred to employ in these rules the velocity in feet per minute, in lieu of in *thousands* of feet per minute, the co-efficient of friction, in lieu of .26881, would become .0000026881; and if the velocity is taken in feet per second, it would become .000967716.

and $k = .26881$, being the co-efficient of resistance in feet of air-column of the same density as the flowing air.

Now by formula (5) we have

$$p = \frac{k\,s\,v^2}{a};$$

giving in this case

$$p = \frac{.26881 \times 1{,}000{,}000 \times (.06 \times .06)}{100}$$

$$= 9.67716$$

feet of air-column as the pressure required.

Taking the flowing air to have had the density due to a temperature of 32°, and to a pressure of 14.7 lbs. per square inch, a cubic foot of it would weigh .080728 lbs., and, therefore, such a column would represent a pressure of

$$9.67716 \times .080728 = .7812 \text{ lbs. per sq. ft.};$$

and hence the horse-power due to the friction of 6,000 cubic feet of air per minute, in passing through such an air-way, would be

$$\frac{6{,}000 \times .7812}{33{,}000} = .142,$$ or about 1-7th of a horse-power.

FOR THE SMALL AIR-WAY.

Proceeding as in the former case, we have

$$\frac{.26881 \times (20 \times 25{,}000) \times (.24 \times .24)}{25}$$

$$= 309.66912$$

feet of air-column as the pressure required for putting the same quantity of air, 6,000 cubic feet per minute, into circulation; being equal to a pressure of

$$309.66912 \times .080728 = 24.9989 \text{ lbs. per}$$

square ft.; giving

$$\frac{6{,}000 \times 24.9989}{33{,}000} = 4.545 \text{ horse-power.}$$

If the *pressure per square foot* was the same in the small as in the large air-way, or .7812 lbs. per square foot, the air-column would be $\frac{.7812}{.080728} = 9.67716$ feet high; and the square of the velocity (in thousands of feet per minute) would by formula (3) be

$$v^2 = \frac{9.67716 \times 25}{.26881 \times (20 \times 25{,}000)} = .0018$$

and hence the simple velocity, in thousands of feet per minute, would be

$$v = \sqrt{.0018} = .042426,$$

and the velocity in feet per minute would therefore be

$$.042426 \times 1{,}000 = 42.426;$$

and this gives for the quantity of air that would be put into circulation in the small air-way, by the same pressure per foot that is required to circulate 6,000 cubic feet per minute in the large one,

$$42.426 \times 25 = 1{,}061 \text{ cubic feet per}$$

minute, as has been stated.

To circulate 1,061 cubic feet of air per minute in the small air-way would, however, only involve the application of

$$\frac{1{,}061 \times .7812}{33{,}000} = .0251 \text{ horse-power,}$$

which, under the conditions of the small air-way, and the assumed pressure, represents the entire power due to the friction of the quantity of air that would circulate in it.

Air, in being heated under a constant pressure, expands 1-459th part of its volume at the temperature of zero of Fahrenheit's thermometer for each degree of temperature imparted to it; 459 cubic feet of air at 0° become 469 at 10°, 479 at 20°, 489 at 30°, and so on. 1,000 cubic feet of air at 32°, the temperature of melting ice, expand to 1,366½ cubic feet, at 212°, the temperature of boiling water. To find the relative volumes occupied by equal weights of air, under equal pressures, but at different temperatures, we have simply to add the constant number 459 to the temperatures, and the sums give the relative volumes. The ordinary pressure of the atmosphere is equal to that of a column of water about 34 feet or 400 inches in height; we, however, seldom employ a difference of more than 2 or 3 inches of water column as ventilating pressure in mines. The pressure of the air is about 2,116 lbs. per square foot, but we seldom employ more than 10 to 17 lbs. extra as ventilating pressure. Owing to the ventilating pressures being

so small, the changes of density in the air of mines (as it circulates), arising from changes of temperature, the mixture of watery vapor or steam, the gases given off, and one or two other causes, give rise to small local pressures in the various splits of air in a mine. In rise splits these local pressures usually operate against the general ventilating pressure, and lessen the quantity of air that would otherwise circulate. In dip splits these small local pressures commonly act in the same direction as the general ventilating pressures, and so add to the amount of their ventilation. This arises from the return air of any split being generally less dense than the intake air.

The laws of ventilation lead us to conclude that if we increase or decrease the total ventilating pressure, and total quantity of air circulating in a given time, where the seam of coal is perfectly level, each way or split will get a *fixed share* of the whole of the air entering the mine, no matter how long or short may be the different splits, and no matter how great or small may be the quantity of air. This is contrary to an old notion, that a short split gets an increasing and a long one a decreasing share of any lessened amount of ventilation, apart from considerations as to the rise or dip of the seam. Not long ago this point was severely tested, by numerous experiments, at several collieries; the results showed that the old idea was a mistaken one, and that the only changes that took place in the *proportion or share* of air going to different splits, with a reduced ventilation, arose from their relative rise or dip, together with the relative densities of the intakes and returns, and had no connection with the mere lengths of the splits. In ordinary cases, where the air of the returns is less dense than that of the intakes, if we have a short level split regulated so that, with the full ventilating pressure, it gets the same amount of air as a long dip split, and if we then halve the total quantity of air circulating, we find that the short level split no longer gets its share, but only a quantity less than that which goes into the long dip split; the very reverse of this is the case where the long split is a rise one; and these results are perfectly agreeable to the laws of ventilation that have been stated. In practice, and with the ordinary splits of air used in mines, except in extreme conditions as to the amount of rise and dip, and changes of density in the air, and in the amount of ventilation, the *share or proportion* of air going into the different splits of a mine is nearly maintained, whether we increase or lessen the total amount of ventilation; and any deviation from this depends upon the rise or dip of the splits, and not at all upon their relative lengths. In practice, then, when any reduction of ventilation has been brought about, we should generally find that the rise splits have been more affected than dip ones, if even the rise splits are shorter than the dip ones, and we should therefore expect to find accumulation of gas in the short rise splits rather than in the long dip splits of the mine. The greater the rise the greater is the danger of this, quite apart from the mere length of the splits, supposing them to be equally well ventilated to begin with.

So far as experiments have gone, they show that if we had a series of equal sized and similarly shaped air-ways, made of different substances, the friction of air in passing through them would differ according to the nature of the substances.

Taking the friction in earthenware pipes at	100
In the air-ways of mines it would also be.	100
In sheet-iron pipes, new and clean	89
In " " rusty inside	10
In cast-iron pipes, sooty inside	20
In " " tarred inside	18
In tin pipes the friction would only be	10

So that 1-10th of the pressure would send the same quantity of air through a tin pipe that would be required to force that quantity of air through an earthenware pipe of the same size in the same time.*

From these laws we learn, that the quantity of air that will pass through any mine is greater or less as the ventilating pressure is greater or less, but not in the same proportion. When the air-ways are the same, the quantity of air only alters in the proportion of the square root of the pressure; so that a fourfold pressure only gives a double quantity of air, and a ninefold pressure only gives a treble quantity of air. But, on the other hand, one-fourth of the pressure still gives one-half of the air, and one-ninth of the pressure gives one-third of the air. The changes in the quantity of air, then, are

* See table, following page.

TABLE showing the values of the co-efficient of friction, represented by the letter k, in the formulæ given at page 212, being the height in feet of air column of the same density as the flowing air, required to overcome the frictional resistance encountered by 1,000 cubic feet of air per minute in passing through a passage having one foot of sectional area, and presenting one square foot of rubbing surface to the air in motion.

Nature of the material composing the pipe or air-way.	State of the internal or rubbing surface exposed to the wind.	Observer's names.	General temperature of the air or gas.	Head of column of the same density as the moving air or gas required to overcome the friction; being the co-efficient of friction $= k$.	Remarks.
Burnt earth	Clean	Peclet	Hot	0.26881	In applying these values of k to the formulæ at page 212 since they are calculated for velocities of which the unit is 1,000 feet per minute, the real velocities in feet per minute must be divided by 1,000, to give the value of v in the formulæ; and v in the formulæ must be multiplied by 1,000 to give the velocity in feet per minute.
Galleries of a coal-mine	Ordinary state	G. C. Greenwell	Cool	0.25436	
Sheet-iron	New and clean	Peclet	Hot	From 0.10583 to 0.06773	
Cast-iron ?	Ordinary ?	Mons. Rudler	Hot	0.08466	
Cast-iron	Sooty	Peclet	Hot	0.05292	
Cast-iron	Old. tarred	Girard	Cool	0.04844	
Gas in pipes } cast-	Ordinary	Mr. Hawkesley	Cool	0.03014	
Water in pipes } iron	Ordinary	Eytelwein	Cool	0.03028	
Sheet-iron	Old and rusty	Girard	Cool	0.02752	
Tinned iron	?	D'Aubuisson	Cool	0.02540	

sluggish as compared with the changes in the ventilating *pressure*, only varying as its square root. The quantity of air, however, is more sluggish still in reference to the *power* employed to cause it to circulate. The quantity of air only varies as the cube root of the power, and of the quantity of coals burnt to produce it; so that eight times the coals only double, and twenty-seven times the coals only treble the quantity of air circulating in a mine, whether the ventilation is produced by furnace action, ventilating machines, or otherwise, so long as the air-ways remain in the same unaltered state. From this we learn, that we must not expect any great general improvement in the ventilation of mines from a mere increase of power; any increase in the quantity of air in the same air-ways is slow, small, and costly, compared with the necessary increase of power required to produce it.

In the same manner these general laws show us, that the quantity of air increases as we decrease or lessen the extent of the frictional rubbing surface; but again, not in the same proportion, but only as the square root of the extent of the rubbing surface. If we could do away with three parts out of four of the rubbing surface, so as to reduce it to 1-4th, other things being the same, we should only double the quantity of air in the mine; if the rubbing surface were reduced to even 1-9th, the quantity of air circulating per minute would only be increased to three times its previous amount. On the other hand, if the extent of workings and rubbing surface were increased to four times, or nine times their previous amount, while the area of the air-ways and the ventilating pressure remained unaltered, the air would only be lessened to one-half or one-third of its previous amounts respectively by such extensions, if we suppose the size of the air-ways and the number of splits of air to remain the same, as well as the ventilating pressure, in each case.

From these laws, then, we learn, that either to increase the ventilating pressure, or to lessen the extent of rubbing surface exposed to the air circulating in mines, is a very slow and very costly mode of proceeding to increase the amount of ventilation, as the quantity of air circulating in a given time alters so slowly with any alteration that may be made in the ventilating power or pressure, or in the mere extent of rubbing surfaces that may be presented to it. For general improvements we must, therefore, look chiefly in some other direction, owing to these being slow and costly modes of increasing the ventilation of a mine.

The same general laws of resistance show us that if we could reduce the velocity of the air, consistently with increasing the quantity circulating in a minute, we should greatly lessen the friction in comparison with the quantity of air circulating, and so obtain an increased quantity for the same amount of friction, or by the same ventilating pressure. This object is accomplished by splitting the air,

so that instead of allowing the whole of the air to traverse the whole of the workings, a separate portion is taken into each different district of workings, and also brought out in a separate channel to a point near the up-cast shaft, after it has done its work. The air, as a whole, thus has as many ways to go in, and as many to come out by, as there are separate splits in the mine; the extent of the rubbing surface is not lessened by this, on the whole, but the area offered to the air is greatly multiplied; and although the velocity of each current may be reduced, still, on the whole, the quantity of air in all the splits is very much greater than if there were only one single current in the mine, even when the ventilating pressure is the same. Splitting the air does not necessarily enlarge the area offered to the air in the shafts, and the increased resistance arising from the increased quantity and velocity of air in them sets a limit to the benefits resulting from splitting the air in a mine. Owing to the resistance offered by the shafts, we dare not have more than a limited number of splits in a mine, because although every split adds to the total quantity of air circulating, still in each separate split the quantity ultimately becomes less and less, and if the number be too great, the current of each becomes too feeble and slow to sweep into the holes, corners, and places driven in advance of the actual current; and besides this, powder smoke is a long time in being carried away from the workmen. Still it is a fact that an additional quantity of air, on the whole, is obtained from every new split that is made.

The following general rules should be observed in splitting the air in mines:

Every principal split of air should commence as near as possible to the bottom of the downcast shaft, and should have a distinct air-way to return in, as nearly as may be, to the furnace or the bottom of the upcast shaft, except in cases where it is necessary to mix different currents, lest some one or more of them may be dangerously charged with gas. Splits of air only commencing far into the workings of a mine have comparatively little effect in increasing the quantity of air.

Where the air-ways are nearly of the same area in all parts of a mine, and the gases given off and the workmen employed are pretty evenly distributed, the length of the runs of the different splits should be as nearly equal to each other as circumstances may permit. The observance of this rule has a tendency to render regulators and other obstructions comparatively needless, and so to increase the amount of ventilation.

If we have a number of splits of air in a mine, each with an equal amount of air, then it is necessary so to obstruct each of the shorter splits as to cause their frictional resistances, when they have their proper share of air, to be as great as that of the longest split, when it also has its due share; otherwise they would get too much air, and the longer ones too little. These obstructions, of course, lessen the total quantity of air circulating.

The increased quantity of air obtained by splitting depends greatly upon the relative depths and areas of the shafts, as compared with the lengths and areas of the air-ways forming the workings of the mine. Supposing a mine to have such shafts and air-ways that when there are five equal splits of air the shaft resistances amount to one-half of the resistances offered by the mine—and this is no uncommon case—then, if before splitting the air at all we had a ventilation of 10,000 cubic feet of air per minute, the following are the quantities of air that would circulate by increasing the number of equal splits, while the entire extent of the workings, and the upcast shaft, and the ventilating pressure all remained the same:

No. of Currents.	Quantities of Air on the whole.	Quantities in each split.
1	10,000	10,000
2	27,892	13,946
3	49,449	16,480
4	71.527	17,882
5	90,789	18,158
6	107,800	17,966
10	141,710	14,171

In this case the coals burnt, whether in a furnace or by an engine driving a ventilating machine, would increase in the same proportion that the quantity of air increased, because the power would increase in that ratio. If the coals burnt, and the power remained unaltered, the results would only be as follows:

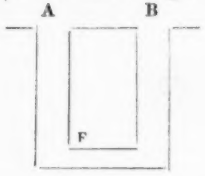
No. of Currents.	Total Quantities of Air per minute.	Quantities of Air per minute in each split.
1	10,000	10,000
2	19,813	9,906
3	29,022	9,674
4	37,121	9,280
5	43,736	8,747
6	48,797	8,133
10	58,556	5,856

Enlarging the sectional area or size of air-ways has a great effect in increasing the ventilation, but it is attended with great cost, and in general terms may be said to be much less effectual than judiciously splitting the air into a series of different currents. The beneficial effects of splitting air are, I believe, more fully appreciated, and the practice is more extensively followed in the Newcastle coal-field than in any other mining district; but even there it too often happens that the splits are made too far from the bottom of the downcast shaft, and are again brought into the same return too soon after they leave the face of the workings. This often arises from pillars being worked away near the shafts, without proper places being left to make additional air-ways leading to and from the more distant parts of the mine. This a very common oversight, and often entails either danger or a serious outlay, which might be avoided by care and forethought.

ON THE MEANS OF APPLYING POWER OR PRESSURE TO PRODUCE VENTILATION.

We have seen that *pressure* is required to put air into motion, and more particularly, to overcome the friction it meets with in rubbing against the top, bottom, and sides of the galleries in mines. We have next to consider the means employed to give rise to this ventilating pressure. There is constantly a pressure of nearly a ton to the square foot in every direction in the air near the surface of the earth, owing to the weight of the air above it; and we must either increase or lessen the amount of this pressure, in order to put the air into motion; and it is only the amount of this increase or decrease, and not the entire pressure, that puts the air into motion and overcomes the friction in mines.

Take the case of two pits or shafts, of equal depth, and having their tops and bottoms on the same level, and filled with stagnant air, which likewise occupies an opening, extending from the bottom of one shaft to the bottom of the other; and suppose that in the first place the weight of the air in one shaft is the same as that in the other, the temperature and other conditions being the same in each, and that the shafts are of the same sectional area or size: in this state the two columns of air exactly counterbalance and support each other, so that there is no motion in the air, and therefore no ventilation is produced; nay, further, if one shaft be ever so much larger than the



other, the air it contains can only press upon that in the smaller one over the area of the smaller section; the air contained in the extra size of the larger shaft resting or pressing upon the sides of the shaft or air-way at the place where the area is lessened, and not upon the air in the smaller shaft; so that whatever may be the relative sizes of the shafts, the air in the one will balance that in the other if the density of the air is the same in each; this may be termed the pneumatic paradox. If, however, by means of a furnace, at F in the diagram, the air in one shaft is heated and expanded, it becomes lighter, bulk for bulk, than the cool air in the other, and no longer balances it; the pressure of the heavier air then overcomes that of the lighter air, and pushes it up the shaft before it, while the cool air from the cool shaft takes its place, but not in a cool state, as it gets heated in its turn in passing over the furnace, so that there is a continual current of cool air going down one shaft which pushes before it a constant current of hot air up the other shaft.

In mines, the air, instead of being allowed to go direct from the bottom of one shaft to the furnace and up the other, is guided by means of stoppings and doors into and along the various passages

forming the workings of the mine, before it is brought upon the furnace or into the upcast shaft, and, by this means, a continual stream of air is made to sweep through the workings and mix with and carry off the gases as they are given off, and this is called the ventilation of the mine.

In some cases, men, boys, and horses require to travel in directions that the air is not wanted to go, and in such cases we cannot build up the way by stopping, but have to place doors to stop the passage of the air; in many cases, the opening of a door to allow a person or horse to pass would have a bad effect by allowing the air to pass through it even for so short a time, and to avoid this evil two doors are employed, so that one may be always closed when the other is open. The use of doors in the principal roads of mines is objectionable where it can be avoided, and is much less common, at least in some districts, than formerly; in other districts of the kingdom the number of ventilating doors is very great, notwithstanding the danger and cost attending their use. The neglect of keeping doors shut has, no doubt, often led to serious explosions of gas in mines. In some cases it is necessary that the route of one split or current of air should intersect and cross that of another, and in such cases one current is carried over or under the other by means of drifts or masonry to prevent their coming into contact with each other; this arrangement is called an air-crossing or bridge. When an explosion occurs, the force of the concussion often destroys air-crossings, and thereby interrupts the ventilation; so that they should be avoided as far as possible, and made very strong where they are used in fiery mines.

It has already been stated that where there are several splits of air in a mine, of different lengths, and offering different resistances, we sometimes find that too little air goes into the longer splits, compared with the quantity going into the shorter ones; and in order to correct this evil, we put regulators or contractors into the shorter ones so as to increase the natural resistance they offer, and cause more air to go into the long splits. Regulators, although useful where they are unavoidable, are not desirable, as they contract the air-ways, and so lessen the total quantity of air circulating in the mine in a given time. As far as may be, the routes of the air should be so proportioned that each split may obtain its proper share of air without using any artificial regulators. Doors, air-crossings, and regulators should be avoided in all cases where the circumstances of the mine admit of it.

In order to find the amount of ventilating pressure, and the power arising from the use of a ventilating furnace, we require to know the weight of a cubic foot of air at different temperatures and under different pressures. Careful experiments show that 459 cubic feet of air at 0°, or zero of Fahrenheit, the common thermometer, weigh 39.76 lbs., when the pressure is 30 inches of mercury of the density due to 32°; a pressure equal to nearly 14¾ lbs. per square inch, which is the ordinary pressure of the atmosphere —but it only weighs 1-30th of this, or 1.3253 lbs., when the pressure is only one inch of mercury; and since 459 feet of air at 0° expand exactly a cubic foot for each degree of heat added, we get the following *rule* to find the weight of a cubic foot of air, at any temperature, and under any pressure:

$$W = \frac{1.3253 \times I}{459 + t},$$

where I = the height in inches indicated by the barometer, and t = the temperature by Fahrenheit's thermometer. At 38°, under a pressure of 30 inches of mercury, 100 cubic feet of air weigh just 8 lbs.; a box 5 feet every way would just contain 10 lbs. of such air.

On one occasion, at Hetton Colliery, when 225,176 cubic feet of air per minute were circulating, the average temperature of the air in the downcast shaft was 43½°, and that of the air in the upcast shaft was 211°. Now, by the rule given (if we take the barometer half-way down the shaft to have shown a pressure of 30½ inches of mercury), the weight of a cubic foot of air, taking the average, in the downcast shaft, would be .08044 lbs.; and the pit being 900 feet deep, this air would produce a pressure of .08044 × 900 = 72.396 lbs. on each square foot by its mere weight. The air in the upcast shaft, owing to its being hotter, would be lighter, and only produce a pressure on each foot = 54.297 lbs.; and hence the

difference of pressure on each square foot of area, between the two columns of air, would be = 18.099 lbs. Now in order to find the horse-power producing ventilation, we require to multiply this difference of pressure of 18.099 lbs. on the square foot, by the number of cubic feet of air circulating per minute, and then to divide the result by 33,000, the number of lbs. raised one foot high per minute by a horse-power. In this case then, we find the ventilating power at Hetton Colliery must have been

$$\frac{\text{lbs.} \quad \text{c. ft. pr. min.}}{18.099 \times 225{,}176} = 123\tfrac{1}{2} \text{ horse-power};$$

225,176 cubic feet of air per minute being in circulation at the time. Some part of the extra heat of the air in the upcast over that in the downcast shaft, would have arisen from the heat of the mine, and would have caused what is called a natural ventilation, even if furnaces had not been used. But natural ventilation is generally very small in amount, and cannot be depended upon, as, in hot weather, the downcast column of air is little or no cooler or denser than the air in the upcast, and, by making the weight or pressure of the two air columns equal, there is a liability to stop all ventilation.

Where furnaces are used to produce ventilation, the deeper the upcast shaft the better; because this gives rise to a longer upright column of hot air, and so causes a greater ventilating pressure, and consequently a brisker ventilation. Furnaces are not well suited for causing ventilation in shallow pits, for this reason; and sometimes machines are fixed at the top of the pit to pump the air through the mine. These machines, for the most part, exhaust air out of the upcast shaft, and the pressure of the denser air in the other, or downcast shaft, causes the current. Such a ventilating machine, like a furnace, acts by rendering the upcast column of air lighter, bulk for bulk, than the air in the downcast shaft; the same effect is sometimes produced by large fans, the machines mostly being worked by steam engines. A few of these ventilating machines are used in the south of England, and in Wales, and a great number are used on the Continent. Ventilating machines of the best construction consume less coals (to produce the same quantity of ventilation) than furnaces, except in very deep and dry shafts. But coals are plentiful at collieries, and the liability of ventilation being suspended by the breakage of the machinery, and the inconveniences attending the stopping of the ventilating machine for repairs to itself or the engine, together with the difficulty of applying ventilating machines to working shafts, render them, in the opinion of many persons, less to be depended upon than furnaces in general. Taking the average of eleven different collieries in the Newcastle district, each pound of coal puts 13,000 feet of air into circulation, by the action of furnaces. In some collieries two or three times as much air is circulated by each pound of coal as in others, depending on the depth of shaft, and its state as to dryness or wetness, and on the friction of the air in the shafts and in the mine itself. There are in Wales some seven or eight ventilating machines at work, producing ventilations varying from 16,000 to 75,000 cubic feet of air per minute. The largest machine is one recently erected at Deep Duffryn Colliery, which, with air-ways of sufficient area, is capable of producing a ventilation of double the latter quantity.

Jets of steam were proposed to produce the circulation of air in mines a few years ago, but by an elaborate series of experiments their effects were found to be far below that of furnaces, and the cost to be very great; the idea of their utility for ventilating mines was therefore abandoned. The useful work contained in a jet of steam probably varies as the cube of the velocity of the steam, so that if the same quantity of water was converted into steam, in a given time, the power contained in it would depend upon the smallness of the jet orifice it had to escape through; by halving the area of the jets we should obtain eight times the power, and should therefore get a double quantity of air through the same mine; by reducing the area of the jets to one-third, we should obtain a treble quantity of air, by the same quantity of steam, in a given time. At least these are the results given by calculations made upon the principles of mechanics, which are found to be true for streams of water and air. I have not taken pains to compare

them with the results of the experiments on steam jets as applied to ventilation, because the results seemed to hold out no hope of steam jets ever being made available for ordinary ventilation. There are, no doubt, temporary and peculiar circumstances under which steam jets may be useful in the production of ventilation, such as cases where it is either unsafe or impracticable to use ordinary furnace action.

Falls of water are sometimes employed in downcast shafts to cause a current of air to descend; but as the water has, for the most part, to be raised again from the mine, and as the effects they produce are small, in proportion to the power employed, this mode of ventilation is seldom used, except where furnace action or other means are necessarily excluded.

OF THE INSTRUMENTS USED IN CONNECTION WITH THE VENTILATION OF MINES.

Barometer.—The pressure of the atmosphere in different states of the weather varies from 28½ to 31 inches of mercurial column, being from 2,016 to 2,192 lbs. per square foot; and it is found that the natural discharge of gas in mines becomes greater as this pressure becomes less, so that the reduced atmospheric pressure, as shown by a barometer, is a warning that an increased quantity of gas may be expected to be given off in mines, and, therefore, calls for increased care and vigilance to keep the ventilation at its greatest point, and for taking precautions against the enemy. The air pent up in goaves and abandoned excavations also expands in volume from the reduction of pressure which causes the fall of the barometer; the increased volume being given out into the air-ways, and often being mixed with gases necessitating careful attention, as the barometrical pressure of the atmosphere is lessened; the more suddenly the pressure falls the more observable are these results. A very *sudden* fall of the mercury is accompanied by a worse effect on mines than a greater fall, provided it takes place less rapidly. An increase or decrease of the pressure of the atmosphere has little or no effect in altering the *volume* of air passing through a mine in a given time, although it alters the *density* and *weight* of such air often to a considerable extent.

A good portable barometer may be used to ascertain the friction of air in passing along air-ways, because the loss of pressure, by friction, as the air circulates, is always taken off the pressure of the air itself; so that in level air-ways the air is less and less compressed as we proceed in the direction followed by the air, and the reduction of pressure is an exact measure, in such air-ways, of the pressure spent on friction.

When the air-way rises or dips, allowances for this have to be made in finding the amount of friction from the pressure of air in this manner. Aneroid barometers appear to be better suited for use in mines than the common barometer or weather glass, as they are more portable, less liable to derangements, and almost equally reliable, at least for comparative indications, which are just as useful as absolute ones in mines.

Thermometer.—The thermometer is used to measure the heat of air in mines; when the fresh air, going down a downcast shaft, is heated, it expands and becomes lighter, and is therefore less able to force the air before it through the mine; in other words, by being heated, the weight of the column of air in the downcast shaft is reduced till it is more nearly equal to that in the upcast shaft, and consequently the ventilating pressure is lessened, and therefore the quantity of air circulating is also reduced in amount. By the use of this instrument we find the difference of temperature between the air in the downcast and that in the upcast shaft, and so are able to calculate the ventilating pressure due to the action of a furnace.

Water Gauge.—The water gauge is merely a glass tube, bent into the form of the letter U with a scale of inches and parts, by which we can measure the difference between the height of the water in one tube and that in the other. It has already been stated that the air loses the pressure that is spent on the friction as it progresses along an air-way. Now, when an air-way happens to turn so as to come nearly parallel to itself, there is often a door or stopping separating the two adjacent parts of the same air-way, and this instrument enables us, in a direct way, to measure the amount of pressure that is spent on friction between the two adjoining parts of the

air-way so situated. The air has less pressure on the outcome or return side of the separation than the air on the intake side, which has not yet met with the friction of the intervening distance of air-way. If the water in one leg of the tube is exposed to the pressure of the intake air, while that in the other is exposed to the lesser pressure of the return air, the greater pressure on the intake leg of the water gauge sinks or depresses the surface of the water in that leg, and raises it in the other leg; the difference of level, which represents the ventilating pressure spent on the air-ways lying beyond the place where it is taken, is seldom so much as three inches, and often only one inch in well ventilated mines. The amount of water gauge can be increased, either by increasing the ventilating pressure, and consequently also the quantity of air circulating in a given time, while the air-ways are in the same state, or it can be increased by falls of material, or other obstructions in the air-ways, even while they lessen the quantity of air circulating; because such obstructions increase the frictional resistance of the air, and the gauge is a measure of that resistance. A water gauge does not show the shaft resistances when used in a mine; the pressure shown by the water gauge is equal to the general shaft ventilating pressure, *less* or *minus* the friction due to the air in the shafts and in the air-ways extending from the shafts to where the gauge is tried. It is also a measure of the resistances the air meets with in the workings lying beyond it, *less* or *minus* any local force, arising from the air in the returns being lighter than that in the intakes, in dip-ways; or it is equal to such friction added to any such pressure that may operate against ventilation from the same cause in the rise-ways or splits of air in the mine; and in cases where the air of the returns is more dense than that of the intakes, the effects arising from the dip or rise of the workings will, of course, operate in the reverse manner upon the indications of the gauge. When the air-ways remain in the same state, the amount of water gauge increases as the ventilation increases, and falls as it decreases; but the proportion of variation of the gauge-pressure is much greater than that of the quantity of air circulating; the *square* of the quantity of air, except in so far as local pressures may interfere, is proportional to the pressure indicated by the gauge, because the friction varies as the square of the quantity of air.

The *Anemometer* is an instrument used to measure the rate at which the air flies in mines. That invented by the late Mr. Biram is the one mostly used in English mines; it is not a very easy matter to find how much each of these instruments requires to be allowed for its own working friction; no perfect rule has yet been established for this purpose, although one is much needed. An approximate rule requires that a constant quantity should be added to the number of revolutions in a minute, no matter what may be the speed of the wind or of the instrument; and that the sum so obtained should be multiplied by another constant quantity, to give the velocity of the air in any terms in which we wish to find it. Coombes's anemometer can be put into or out of gear by pulling strings attached to it; this instrument is said to give very correct results, and is greatly used on the Continent; it is, however, more troublesome to use than Biram's anemometer, and is seldom seen in our mines. There are a few other kinds of anemometers; but a good and simple instrument, or mode for finding the velocity of air in motion, has probably yet to be contrived.

The Hygrometer.—In fine experiments, the hygrometer is used to ascertain the proportion of moisture in the atmosphere of mines, from whence its density and also its capacity for heat are found. Mason's wet and dry bulb hygrometer is better adapted for use in mines than the more delicate one of Daniel. The return air in nearly all mines is found to be saturated with vapor of water; that is to say, it contains the greatest quantity of vapor that can exist in it at its temperature; and a portion of vapor is condensed by the least degree of cooling that takes place in the air. An atmosphere saturated with vapor is lighter, bulk for bulk, than another at the same pressure and temperature, but containing less vapor.

In the discussion which followed—

Mr. Atkinson said: Supposing you have a long split and a short one in the

same mine, and you regulate or contract the short one by an artificial obstruction until the quantity going into each is equal; then supposing, from some cause or other, the general ventilating pressure is gradually reduced: what would be the result? Would the short split get half of the remaining total quantity of air, or would it get less or more? That question would have been answered in my younger days by saying that the short split would ultimately take the whole of the air, and none would go to the long one. Now, however, it is a fact, which I have proved over and over again, that if the air-ways are level, and you reduce the ventilating pressure, each split will take its original *proportion;* but if the long one is a dip-way and the short-way is a level one, on reducing the gross quantity of ventilation the long-way gets more than its original *share* of the reduced quantity, and so takes the lead of the short split. If, on the other hand, the long split is a rise and the short a level, on reducing the gross quantity the long split gets less and the short one gets more than its *share*. Supposing one split gets 60 per cent. and the other 40 per cent. of the total to begin with, if the air-ways are level, each will get the same percentage when the gross amount is lessened. Just the reverse results take place if you take the proportions from any standard amount of ventilation, and then *increase* the gross quantity, where there are rise and dip splits, supposing the air in the returns to be hotter and less dense than in the intakes in each case. If, however, the returns were so mixed with carbonic acid gas and so cool as to be more dense than the air in the intakes, then the reverse results would ensue on increasing or reducing the ventilating pressure, where the splits are not level. We had a long discussion about this at the North of England Institute of Mining Engineers. Some one suggested, after the Lundhill accident, that instead of having air kept so much in one current, if they had taken it up each bank on separate splits, they would have got a much better ventilation; but the objection was raised that in the event of the furnaces being low and the general ventilation being reduced, the far-off places would get no air; it would all run through the "short cuts;" and it was to correct that idea that the matter was made the subject of investigation by careful experiments. Further, the benefit of splitting air depends in a great measure upon the proportion of resistance that occurs in the shafts as compared with that which occurs in the workings. The total pressure applied may be divided into two separate items, one of which is employed to overcome the shaft friction, and the other to overcome the resistance in the workings. Generally speaking, you can subdivide the workings till you reduce the friction very materially; but the friction in the shaft is, of course, always the same for a given quantity of air, and it is only from reducing the friction in the workings, that the beneficial results of splitting the air are derived. As to dumb drifts, in some collieries, where discharges of gas occur, it might be expedient to use them; but he would rather have sweeping ventilation, as a rule, and a mixing of the return air from the place where the gas was given off with that from the other ways, so as to render it safe before reaching the furnace. If you supply the furnace with fresh air, you never get with the same furnace the same amount of air into the workings, and our object is to cut down the amount of friction in the downcast and upcast shafts. There is one rare case where that does not hold, and that is if your returns were so charged with carbonic acid gas, so fearfully charged with it, that they would not let the furnace burn, you would have nothing else for it but to use fresh air, but you would use it at the expense of not getting the same amount of ventilation as you would get with ordinary air.

It may not be generally known that the highest points of the chain of the Andes are sinking. In 1745, when measured by La Condamine, Quito was found to be 9,596 ft. above the sea. Humboldt, in 1803, found it had fallen to 9,570 ft.; Boussingault, in 1831, was astonished to find it was only 9,567 ft.; Orton, in 1867, found it reduced to 9,520 ft.; while, finally, Reiss and Stubel verified that in 1870 it had shrunk to only 9,356 ft. above the sea-level. Quito, therefore, has sunk 240 ft. in 125 years.

THE HOTCHKISS REVOLVING CANNON.

BY PARK BENJAMIN.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

DURING the last three years scattered and incomplete reports regarding the performances of the new Hotchkiss revolving cannon have appeared from time to time in the European scientific and military journals. Derived, as these mainly were, from unofficial sources, and tinged more or less with individual expressions of opinion, they have lacked that perspicacity which would enable the reader unconversant with the weapon to form an intelligent and fair idea of its efficiency, both intrinsically and as compared with other and kindred arms. Experiments, mainly under the auspices of the French government, have been continued up to as late as July last; so that the results obtained from the official reports of all the trials are now for the first time, as a whole, laid before the public.

To those unfamiliar with the weapon a brief description of the principles governing, as well as the details of its construction, may not prove unacceptable. The gun is not a mitrailleuse, according to the common understanding of that term. It is to be sure a bundle of barrels, rotated by suitable mechanism, which discharge a hail of projectiles; but the former, instead of having bores of the size of those of small arms, are an assemblage of rifle cannon of 37 millimetres calibre; and the missiles are conical percussion shell, weighing 507 grams each, and made up as fixed ammunition with metallic cartridges charged with from 100 to 110 grams of powder.

The barrels are of cast steel, five in number, and are grouped in a frame about a central shaft, through the rotation of which they are turned about it as an axis. Inside the breech, and fastened to the extremity of this shaft, is a disk, the rear face of which is provided with ducts, which enter the grooves of a worm-wheel which is mounted on a shaft extending transverse the breech portion. It is clear that if, by a crank on the outside, the transverse shaft be turned, then, through its worm-wheel and the spur disk, the axial shaft of the barrels will be rotated. The groove on the worm-wheel is so cut that for an instant of its revolution the spur disk, and consequently the barrels, are left motionless. At this instant the firing takes place.

From the transverse shaft motion is imparted to all the rest of the machinery. The bearing of the left hand end is inside the breech, and at the extremity of the shaft therein enclosed is a short arm at right angles. This carries a pin which, working in a slotted piece, gives the latter a to-and-fro motion when the turning crank outside is revolved. The slotted piece moves a rack, the rack through a pinion another rack; and the last is connected with a small piston which through this mechanism is made to travel forward and back in a conducting trough. Just above the trough, and opening into it, is a door which, when the piston is drawn back, falls open, allowing a cartridge to slide down an inclined plane above and into the trough. The piston then travels forward, drives the charge into the barrel, which stops for an instant in front of the passage, and at the same time a stud on the upper part of the piston pushes the feed door shut. We mentioned above two racks, one of which carries the loading piston already described. The mechanism is such that as one rack travels forward the other, which is underneath, runs back, and *vice versa*. The object of the lower rack is to carry a hook-shaped extractor, which, when pushed forward, catches in the rear rim of the spent cartridge shell which happens to be in the barrel immediately adjacent. As the shell is drawn out it strikes an ejector, and is thus thrown to the ground through an opening in the breech-block.

The new cartridge is now pushed in by the piston for its entire length, but its end is left slightly protruding in view of an inclined plane which is cut in the metal of the breech, and which completes the forcing in of the load as the barrels are turned.

While all of the above mechanism is located in the left of the breech, the firing apparatus is arranged at the right. On

the transverse shaft, the same above mentioned as worked by the outside crank, is a cam which, as the shaft is revolved, pushes back an arm connecting with a spring firing-pin, thus cocking the piece. When, however, the loaded barrel arrives opposite the end of the pin, the cam-shoulder slips from under the arm, the pin is driven forward by its spiral spring, and the charge is exploded.

It is, of course, impossible to follow the operation of these parts in detail without the aid of drawings; but from the preceding the reader will be enabled to form a fair general idea of the simplicity of the mechanism. The projectile, as before intimated, is a conical shell, the fuse of which consists of a case which in its under part contains a lead plunger with a brass envelope. The plunger holds the fulminate, and has a small powder chamber. It is fastened by a safety plug of lead in the under hole of the fuse, and closed by a plug which has a point, against which the plunger drops at the sudden stoppage of the projectile, the concussion exploding the fulminate. There are ingenious arrangements for pointing to nice angles, the gun being placed on a saddle having trunnions fixed to the carriage. Further explanation may be now omitted in order to turn to the consideration of the reports before us.

Ballistical Results Obtained with the Hotchkiss Revolving Cannon at Gavre, France, in January, 1874.

Initial velocities measured at 25 met. distance from the muzzle. French Ripault powder; density of charge, 0.908.*

Weight of charge.....	100 gr.	110 gr.
Weight of projectile.....	507 gr.	507 gr.
Mean initial velocity.....	421.7 met.	432.9 met.

* Since this period some new ballistical improvements have been made on this gun; at the trials made by the French government at Bourges in June, 1874, a mean initial velocity of 458.8 met. was obtained, with 110 gr. powder, and a projectile weighing 507 gr.

The ranges at this trial were:

Elevation	2° 40′	5°	10°	15°
Range in met.....	1,003	1,723	2,842	3,460
Elevation	20°	27°	30°	35°
Range in met	3,916	4,240	4,580	4,700

Range, Deflection, and Deviation; weight of projectile, 507 gr.; charge, 100 gr., Ripault powder.

Total angle of elevation.....	34° 47′
Velocity { parallel to line of fire	3.1 met.*
of wind, { perpendicular to do.	1.1 met.†
Density of air.....	1.247
Mean range.....	4,014 met.
Mean deflection, to the right.....	32.2 met.
Mean deviation { longitudinal.....	25.0 met.
{ lateral	1.5 met.
Mean angular deviation (in minutes)	0′ 14″
Mean deviation in velocity.....	0.0114 met.

From the above table it will be seen that the accuracy of fire is more remarkable than has been known to have been obtained from any other gun; the proportion of the mean longitudinal deviation to the range being only 0.00623, and that of the mean lateral deviation 0.00039, while the mean variation in velocity, 0.0114 met., is practically nothing.

MAXIMUM RANGE.

The maximum range of the Hotchkiss revolving cannon of the model of 1874, with a projectile weighing 520 gr., and a charge of 120 gr., is about 5,000 met. The corresponding angle of elevation is 35°.

BURSTING OF THE PROJECTILES.

A number of projectiles charged with 25 gr. of musket powder were burst by means of electricity in a wooden box measuring one cubic metre filled with wet sand, so that all the fragments were obtained after the explosion.

The average number of fragments from each projectile were fifteen of iron, three of the brass coating, and the fuse, comprising:

Three	pieces	weighing	between	100 gr.	and 50 gr.
Five	"	"	"	50 gr.	" 25 gr.
Eleven	"	"	"	25 gr.	" 10 gr.

SENSITIVENESS AND GENERAL ACTION OF THE PERCUSSION FUSE.

At the trial of the revolving cannon at Gavre several shots were fired into the sea at angles of 2′, + 15′, + 2°, + 3°, + 5°, and all the projectiles burst on striking the water.

Twenty-five fuses were fired at different angles from 20° to 34° 47′, and no missfire occurred.

* From ahead. † From right.

At a trial in Romania in July, 1874, three hundred and twenty shots were fired, at elevations from 3° to 6° 30′, and no fuse was found which had not acted properly.

PENETRATION OF THE PROJECTILES.

The gun was placed at 150 met. distance, before a target of oak 12 cm. thick. Three shots were fired, all penetrating the target, the first shot bursting a few metres behind it. The second shot burst 400 met., and the third shot 300 met., behind the target after having struck the ground.

Three shots were fired against a cast-steel plate 10 mm. thick, at the same distance of 150 met. from the gun. The first two shots penetrated the plate, and burst a few metres behind it. The third shot, which was directed against an oak framework 25 cm. thick, to which the plate was fastened, penetrated the latter, and burst inside the wood, tearing and splitting it about 1,200 mm. in length.

GENERAL REMARKS ON THE SYSTEM.

On thus examining the results obtained by the revolving cannon, it is found to be an arm of very superior capacity and of well calculated proportions. The power of the powder is utilized in a high degree; for, with a projectile weighing 520 gr., and with a charge of about one-fifth, there results an initial velocity of 458 met., and a range of about 5,000 met.—an effect which only recently has been obtained with regular field artillery; while the precision of the fire in both range and direction is remarkable in the greatest degree, surpassing anything that has been obtained up to the present time.

The trajectory of the gun is, for an effective range, low, and a very precise, rapid, and effective fire can be kept up at a range of 4,000 met., corresponding with an elevation of 20°.

This machine-gun has, besides its great accuracy and range, the peculiar and valuable advantage of firing explosive projectiles, producing the greatest moral and physical damage to the enemy, and enabling the gunner at the same time to rectify its fire by observing the explosions of falling missiles.

As there is no recoil and no change of direction during the fire, the gun, once laid, will continue to throw from *sixty to eighty explosive shells per minute*, at ranges approaching to those of field artillery, on the same spot, or on various points of line requiring the same elevation, without any further operations than those of supplying the gun with cartridges, turning the crank, and regulating the lateral adjustment.

The essentially mechanical arrangement of the system is simple and compact; the working parts are strong, and of simple form, and they are all encased within the solid breech, and not one of them is exposed to the shock of discharge.

The brass coating of the projectiles affords an excellent bearing for the grooves of the rifling, and at the same time obviates the difficulties of leading and fouling of the bore, while the saw or tooth-like grooves cut into it reduce the friction to the greatest possible extent, thus giving a satisfactory velocity with a minimum of strain on the gun.

The metallic cartridge always produces an absolutely gas-tight closure of the breech.

Another feature of this arm, to be well estimated in actual service, is its facility of manipulation. The operation of loading is simple, and the gunners only require the briefest instruction—as, besides the laying of the gun, nothing is necessary but to supply it with cartridges, and to revolve the crank.

COMPARISONS OF THE RESULTS OF THE HOTCHKISS REVOLVING CANNON WITH THOSE OBTAINED BY OTHER GUNS AT GAVRE.

A part of the before-mentioned trial at Gavre in July, 1873, comprised some practice with a revolving cannon under exactly the same conditions as with four Gatling guns of different calibres, which had shortly before been under experiment by the same commission, with a view of comparing the effects of these different kinds of arms.

The guns under test were as follows:

Nature of Arm.	Weight of Projectile.	Charge.	Bursting Charge.	Weight of Gun.
36.68 mm. Revolving Cannon.....	490.00 gr.	85.00 gr.	20.00 gr.	475 kil.
25.5 mm. Gatling Gun.....	256.85 gr.	31.77 gr.	.....	347 kil.
16.6 mm. " "	97.52 gr.	19.33 gr.	.....	335 kil.
11 mm. " "	24.20 gr.	5.16 gr.	.....	170 kil.
11 mm. Mountain Gatling	24.20 gr.	5.16 gr.	.....	64 kil.

First Experiment.—Firing against a batallion of infantry in columns, divided into three troops or companies, represented by three Targets, each 1.80 met. high, and 70 met. long, placed at distances 70 met. apart. Distance of all guns from the first target, 1,650 met.

TABLE I.

Nature of arm.	Angle of Elevation.	Number of Rounds Fired.	Expenditure of Ammunition in Kil.	Number of Hits.			Total Number of Hits.	Percentage of Hits.	Number of Hits per Kil. of Expended Ammunition.	Effective Power.
				1st Target.	2d Target.	3d Target.				
36.68 mm. Revolving Cannon...	6° 36′	80	53.6	3	39	13	55	70	1.04	36.40
11 mm. Gatling Gun.....	8° 25′	400	15.7	19	24	2	45	11.25	2.85	26.32
11 mm. Mountain Gatling...	10° 15′	435	17.1	6	10	0	16	3.70	0.89	8.62

The superiority of the revolving cannon is here well marked.

Second Experiment.—Firing against a batallion of infantry in columns, divided into platoons, represented by six Targets, each 1.80 met. high, and 35 met. long, placed 35 met. distance apart. Distance of all guns from first target, 1,795 met.

TABLE II.

Nature of Arm.	Angle of Elevation.	Number of Rounds Fired.	Expenditure of Ammunition in Kil.	Number of Hits.						Total Number of Hits.	Percentage of Hits.	Number of Hits per Kil. of Ammunition Expended.	Effective Power.
				1st Target.	2d Target.	3d Target.	4th Target.	5th Target.	6th Target.				
36.68 mm. Revolving Cannon.	6° 30′	80	53.6	2	49	42	25	20	1	139	173.7	2.59	90.32
25.5 mm. Gatling Gun.....	6° 1′	300	113.4	12	76	66	12	3	3	172	57.33	1.45	33.82
16.6 mm. Gatling Gun.....	6° 14′	216	36.5	3	6	6	20	5	1	41	18.9	0.90	31.49

In this case, also, the revolving cannon in results much surpasses the other guns.

By the aid of extracts from the "Official Report on Competitive Experiments of the Montigny Mitrailleuse and Gatling Guns, at Shoeburyness, in August and

September, 1870," there are means of making a comparison of the Hotchkiss revolving cannon with the guns under consideration in that trial.

The following tables comprise the practice at ranges of 1,280 met. and 1,890 met., as a comparison can only be then made if the ranges and other circumstances do not differ largely from each other.

TRIALS AT SHOEBURYNESS IN 1870.

FIRST EXPERIMENT.—Firing against a column of targets 16.44 met. long, representing 90 infantry, divided into three troops or companies 18.30 met. apart. Distance of all guns from first target, 1,280 met. Time of firing, two minutes.

TABLE III.

NATURE OF ARM.	Number of Rounds Fired.	Number of Hits.	Percentage of Hits.
25.5 mm. Gatling Gun.....	255	99	38
16.6 mm. " "	239	236	98
11 mm. " "	545	104	19
Montigny Mitrailleuse.....	272	68	24

SECOND EXPERIMENT.—Firing against a column of targets 8.22 met. long, representing 45 infantry, divided into three troops or companies 27 met. apart. Distance of all guns from first target, 1,890 met. Time of firing two minutes.

TABLE IV.

NATURE OF ARM.	Number of Rounds Fired.	Number of Hits.	Percentage of Hits.
25.5 mm. Gatling Gun.....	238	99	41
16 mm. " "	338	164	48

CONCLUSIONS FROM THE FOREGOING.

In comparing the results obtained in Table I., we find that the number of hits per 100 shots fired from the revolving cannon, during an equal length of time, are six times greater that those obtained with the 11 mm. Gatling gun, and twenty times greater than with the 13 mm. Mountain Gatling.

The number of hits per kil. of expended ammunition is less for the revolving cannon than for the Field Gatling, but more than for the Mountain Gatling, while the effective power* is:

For the Revolving Cannon.....36.40
For the Field Gatling.....26.32
For the Mountain Gatling..... 8.62

In Table II. the percentage of hits of the revolving cannon is three times higher than of the 25.5 mm. Gatling, and nine times higher than that of the 16.6 mm. Gatling, and the number of hits per kil. of expended ammunition is nearly double those obtained with the 25.5 mm., and nearly three times that of the 16.6 mm. Gatling. The effective powers are:

For the Revolving Cannon.....90.32
For the 25.5 mm. Gatling..... .....33.82
For the 16.6 mm. Gatling.....31.49

* By the effective power of an arm is understood the compound quality which is governed by the number of hits on the targets, the line of firing, the distance the targets are placed from the gun, and the dimensions of these targets.

In the determination of the effective power, there are, besides the unit of time, two quantities, which are fixed by the conditions of the practice, viz.: the range and the dimensions of the targets. As these are chosen analogically to the circumstances under which the arms to be tested are subjected in actual service, we have the means of comparing different kinds of arms under the practical conditions they are employed in; for example, in Table II. is understood by effective power, the number of hits made in a minute of time by a gun on six targets 1.80 met. high and 35 met. long, placed 35 met. distance apart; distance of gun from first target, 1,795 met. This definition of effective power is used by the French artilleries, and, in the present case is taken out of the "Memorial de l'Artillerie de la Marine" (3de livraison, 1874), where the comparative trials of the Hotchkiss revolving cannon with the Gatling Mitrailleuses are reported.

Observe that the effective power under the above stated conditions affords no judgment of the weight of ammunition expended, and as there are certain cases where it is not only important to know what effect can be produced with an arm, but what quantity of ammunition it requires to produce this effect, it is necessary to compare these two figures with each other, and we can thus form a true judgment of the merits of the different arms.

That is to say, in this case the revolving cannon obtained an effect three times as destructive as the Gatling guns, with an expenditure of half the weight of ammunition.

Comparing the number of hits per cent. of the guns in Tables III. and IV., with the revolving cannon in Tables I. and II., the number of hits is higher for the revolving cannon than for all other guns.

Note the line of firing in Tables I. and II. was one minute, while the lines of firing in Tables III. and IV. were two minutes; so that, considering the time of firing, the number of hits is much greater for the revolving cannon than for the other guns.

It must also be remarked that these results were obtained with a revolving cannon of the first model, built in 1871, of inferior ballistical capacity, with a projectile weighing 490 gr. and a charge of 85 gr. Since this time the inventor, M. B. B. Hotchkiss, has, from his own experience, and according to some valuable suggestions and indications made by the committee of experiments at Gavre, augmented the power of his arm, so that there is reason to expect from the guns of most recent date, using a projectile of 520 gr. and a charge of 120 gr., results much superior to those obtained at Gavre in January, 1873; and it is to be regretted that sufficient data for making a comparison of the effects obtained with the latest models did not exist.

Judging from the general results, it may be concluded that the Hotchkiss revolving cannon is in most respects superior to and can be used with greater advantage than any other arm tested in the tables from I. to IV.

For all purposes of defence, or on open ground, at ranges approaching field artillery, for damaging material, and reaching troops behind cover, for the employment in advanced trenches or field-works, and for repelling cavalry attacks and assaults on forts, the arm will be a formidable one. This gun may be applied for offensive purposes in nearly all cases where light artillery can be advantageously used. It is, besides, a valuable weapon for marine use, when placed on the decks of ships, or for arming boats, and for landing purposes.

For the last-named purposes, where it is not necessary that the gun should be absolutely without recoil, a lighter model is manufactured, its weight being only about 300 kil.

In the Hotchkiss revolving cannon the advantages of the mitrailleuse are combined with the long ranges, precision, and moral effect of the *explosive shells of artillery*. The projectiles have, also, to a certain extent, the penetrating power of the same.

The superiority of the revolving cannon over mitrailleuses becomes the more remarkable the greater the distance at which it is used; while for ranges up to 250 or 300 met., and for purposes of flank defence, canister shot also are used with success.

The system of the Hotchkiss revolving cannon is not restricted to any particular calibre; it can be constructed either as a mitrailleuse, which employs small-arm ammunition, or of calibre much larger than the before-described gun; thereby affording the advantage of uniformity in the system of armament.

Two essentially different calibres besides the 37 mm. calibre revolving cannon are now manufactured—the one is known as the "Hotchkiss mitrailleuse," 16 milimetres calibre, and another gun designed especially for use in forts or fortified positions, this latter with a calibre of 52 mm. and a projectile weighing 2.5 kil.

WHATEVER may be in store for our coal beds in England, we need not despair of a plentiful supply of the useful mineral when the Chinese fields are fully developed. In Sze-Chuen, coal occupies an area of 100,000 square miles. Starting from the great plain of China on the west, there is a plateau of coal, overlying a limestone formation, extending to Shersi and Kansu for a distance of about two hundred miles. These beds lie horizontally, have an average thickness of 30 feet, and an area of 30,000 miles. According to Baron Richtofer, to whom we are indebted for the preceding information, the coal is of excellent quality. We hope, however, that no one will waste one ounce of coals because we may get a supply at some distant day from China.

MINERAL RESOURCES OF BOLIVIA.

From the "London Mining Journal."

THE absolute necessity for the ready means of transport, in order to render the development of the mineral and general industrial resources of a country profitable, was probably never more clearly shown than in the case of Bolivia, whose rich deposits of minerals, and enormous natural productions, remain comparatively worthless, owing to the absence of any facilities whatever for getting the produce to the coast, or materials to the mines. To enable capitalists thoroughly to comprehend the requirements of Bolivia, and provide for them with advantage to themselves, Mr. Avelino Aramayo prepared a careful history of Bolivian industry and commerce, and he has reprinted extracts from his book in consequence of the increased interest now felt in the country. After visits for many years to Europe and America, connected with industrial and commercial matters, Mr. Aramayo ultimately devoted himself to mining affairs, these being the principal occupations in Bolivia, and at a period when this branch of industry was in general decay. He proposed to advance mining operations by improving the modes of working, and after 12 years of constant application he succeeded in stimulating progress in two of the undertakings with which he was connected, by showing the cause of their backwardness; still, mining in general continues in a depressed state. The careful study he made of the old system, the obstacles he encountered to establish the new, with the daily discoveries of mines, showed to him that the main cause of the want of success was that the mines existed so far in the interior, and in the want of roads and connection with the commercial world. He concluded that to extricate mining from such an unsatisfactory state, it was at least necessary to have a railway from the Pacific Coast to the interior.

It is to mineral industry, in Mr. Aramayo's opinion, that the Bolivians should dedicate themselves, for the reason that it is the best adapted to their territory, naturally so metalliferous, to their inland situation, to their present industrial and economic position, and that it is also in conformity with their historical traditions. He remarks that the mines that in former times have produced immense wealth are at present in the most abject state of depression. In 1846 they had 10,200 mines of silver and gold, of which only 200 were in work, and 10,000 abandoned; and from 1846 to the present time the yield has gradually decreased, so that excepting a very few miners who have been fortunate enough to come upon a vein of metal of extraordinary richness, all the rest are in a miserable position, and the best arranged enterprises soon decay and go to ruin. Mr. Aramayo has undertaken the task of explaining the cause of this, and suggesting means for its removal. They have a large number of mines, and with most extensive veins; of these in olden times only a few have been worked to a certain depth, and are untouched below, where ore exists in abundance and of superior quality; the proper working of these would give incalculable wealth. The geological character of the hills and mountains is essentially metallic, and, if we except some few, the formation of recent origin, and caused by partial and isolated cataclysms, all the rest carry with them more or less abundance of gold and silver, or at least of copper, lead, tin, and iron. Not without foundation is it believed that the great chain of the Andes, running through Bolivia in various directions, is in great part metalliferous, and has hidden in its depths virgin deposits of gold and silver, which some day will give the world immense wealth. Taking into account the opinions of the old miners, as well as his own observations, it is obvious that they did not penetrate sufficiently in depth, limiting their explorations to little distance from the surface, and abandoning one rich mine for another the moment they met with the slightest obstacle.

It cannot be denied that the old miners wanted the most common and indispensable knowledge for the exercise of their industry; nor could it have been otherwise, for at the time of the Spanish con-

quest, and even afterwards, they had the most imperfect information of mechanics and geometry, sciences on the principles of which are founded the operations of mining, or the art of discovering where the metals are to be met with. In working the veins they kept to no rules, nor followed any part of art, nor practised any preliminary operation which would have prolonged the duration of the mine, or saved expense in extracting the ore or the water. It is to be observed, too, that at no period was there employed larger capital in mining with the object of assuring permanent production. Of the great sums the Spanish Government expended in the construction of the lakes of Potosi, the Mint, and the royal socavon, or adit, there never was set apart any considerable amount for the encouragement of one undertaking with views for the future. The miners on their own account have worked the mines as well as they were able, some being ruined, others obtaining profits, but the general result has been disastrous, as can be well understood, on account of the small capital employed, and by miners so little experienced in the business of risk. Without a centre of help or combination to sustain them, and for want of union, they have gone on disappearing. Mr. Aramayo remarks that there are nearly 2,000,000 of Indians, of whom at most 10,000 are employed in mining, and that there can be obtained as many workmen as may be required whenever the progress of mining is enabled to offer labor better conditions. The Government monopoly of silver bullion has ceased, so that the facilities for profitable mining are increased. By the law of Sept. 11, 1872, the exportation of silver from Bolivia is free. As to the want of security in Bolivia which is supposed to exist, owing to the instability of the Government, Mr. Aramayo explains that the frequency of these political convulsions has limited their action to a certain class of society making politics their business, and who live in its ups and downs; but the working class has always been reserved, and up to a certain point sheltered from their influence, and only indirectly suffering from them. There is still more in this respect, and he can say with satisfaction that Bolivia is one of those countries in the world noted for the greatest respect for property; excepting in one or another isolated case, they have no examples in their revolutions that violent hands have been laid upon personal property.

In former times when the discoveries were made, the veins of silver being found on the surface of the mountains, some in prodigious abundance of metal, others less, but all more or less rich, the facility of working gave occupation to the thousands of Indians, who at little cost gathered great heaps of ore from the vein they chose among many. The richer portions of the ore were worked by smelting in the guairachinas—ancient furnaces—the inferior quality was put aside until grinding mills were established. Lipez, Potosi, and Oruro were great places of mines where machinery could be established in their vicinities, and the only spots where large quantities of ores could be extracted in consequence of the facility there was of carrying it to the ingenios, or grinding mills, &c., situated at short distance from the mines. All the ores at that period were the pacos (chlorides), easily manipulated; thus machinery was only used in pulverizing the ore. Amalgamation was performed by repaso—trodden by the feet of innumerable Indian "mitayos"—forced labor. When negrillos and azufrados replaced the pacos, the works which had been erected became useless, and the treatment of ores which merely required roasting, was regarded as hopeless. The only conclusion to be drawn from Mr. Aramayo's volume is that although Bolivia is rich in minerals, they are worthless to her until she has increased facilities of transport. Without roads and railways, the Bolivian miner has no market wherein to sell his products; neither can he purchase as wanted the articles required for his works, so he is obliged to collect large quantities of all he requires in anticipation. With improved means of transport, Bolivia will be able to supply not only gold and silver, but copper, tin, and other metals also, and the time is evidently fast approaching when it will form a favorable field for the enterprise of British capitalists.

THE APPLICATION OF THERMO-CHEMICAL THEORIES TO GUNPOWDER.

(Abstract from "Iron" of paper by M. CASTAN, in the "Revue d' Artillerie.")

CHEMICAL combinations, in their formation, liberate or absorb a certain quantity of work, which may, in general, be estimated in the state of heat. The union of hydrogen, of carbon of potassium, with oxygen, liberate respectively 34,500, 47,000, 62,000 calories per equivalent of the products formed; the union of chlorine with nitrogen, and that of sulphur with carbon, absorb, on the other hand, 55,000 and 24,500 calories per equivalent of these substances combined. The universal principle of the equality between action and re-action governs this order of phenomena, like all those of matter. So it is necessary to expend a certain quantity of work, to resolve water, carbonic acid, and potash, into their elements; while the decomposition of chloride of nitrogen and of sulphide of carbon, on the other hand, liberates it. The study of the union of substances and its laws, from this point of view, forms the science of thermo-chemistry.

We may divide explosive bodies or mixtures into three classes: 1. A mixture of substances the sudden combination of which, under certain influences, liberates work. (Type: detonating mixtures). 2. A combination that has absorbed work in its formation, and may restore it rapidly in its return to its primitive elements. (Type: chloride of nitrogen). 3. A mixture or a group of elements belonging to these two classes. (Types: gunpowder, in which the charcoal, sulphur, and saltpetre emit work in forming new combinations, which are rapidly produced by the liberation of the work stored up in nitric acid, gun-cotton, picrate, &c.)

The application, then, of thermo-chemistry to explosive bodies, enables us, knowing the heat of formation of all the combinations composing them, and that of the products of final decomposition, to calculate the work stored up in these bodies, and the total work which they can emit. We may thus be able to classify explosive bodies of different composition, with reference to the maximum work they can produce. But, just as in the mechanics of machines, the work received depends not only on the motor force, but also on its mode of use in the machine, so (and with greater reason) in the application of explosive bodies, from the imperfection of the receiver, it is not so much the total work stored up in these substances that has to be considered as the work which can be obtained from them in an effective manner; and it is from this point of view that we proceed to consider the powders used in war.

Influence of Proportions (*dosage*).—The work contained in a powder is merely a function of its ingredient proportions, which may vary within limits wider than those of convenient ballistic application. Yet, if we consider the proportions actually adopted by manufacturing authorities, we find they vary little from each other, and it is not without reason; the question of conservation and hardness of grain tends to bring down the proportion of charcoal and increase that of the sulphur, which, in its turn, is limited by the dirtying of the arms. Owing to the conditions imposed by the service, the differences of work contained in the various powders will hardly reach 1,500 calories in more than 600,000 given by the detonation of 1 kilogramme of these products. This fraction of 1-40 shows that from the present point of view, the choice of a proportion of ingredients is of little importance.

Influence of Physical Properties.—The great differences observed between the effects of powders arise from their physical properties, and are especially revealed by their mode of use in guns. If powder be burnt in a close vessel, as MM. Noble and Able have done in England, it is found that all the kinds of powders which do not differ much in their proportions, but whose physical properties (density, size of grain, &c.) vary within very wide limits, give nearly the same pressure of 32 to 37 tons per square inch. The mode of trituration itself has no great influence on detonation in a closed vessel, as the observations of MM. Roux and Sarrau have proved. But if the gases can do

mechanical work during detonation—that is to say, if this occurs with expansion—the influence of physical properties appears at once. Thus, in the experiment of MM. Noble and Able, if a hole be made in the vessel for escape of the gases, the powders immediately range, with reference to interior pressure, in this apparatus, as in cannons; that is to say, the increase of the density and size of the grain produce considerable diminution of the pressure. In the case of powders with the same proportion of ingredients and the same grain, but differing in the process of trituration, one is obliged to give stamped powders a density about 0.08 less than that of powders triturated three hours under millstones, in order to obtain the same effects with the same charge. Taking powders triturated in the same manner, having the same proportions and the same grain, a difference of density of 0.09 lowers the velocity more than a third, from a value of 400 to 260. These differences, one sees, are much more considerable than those arising from the most extreme variations of proportion in practice, but as they do not proceed from a difference of work stored up in the powder, but rather from varieties introduced in the utilization of this work, they can only be brought forward in evidence in the firing of guns.

Justification of the Composition of Gunpowder.—All that has been said on the secondary *role* of proportions of powder, reduced to the limits imposed by their employment, applies only to a mixture of saltpetre, sulphur, and charcoal. It is certain that by varying, not the weight, but the nature of the constituents, we may obtain very different effects, which the application of the thermo-chemistry of the present enables us to anticipate with sufficient distinctness.

The results of this study show that our ternary mixture is one of the least powerful explosive substances, and point to a number of bodies the substitution of which for the actual constituents would greatly augment the total work contained in the powder. But we should be constrained to such a radical change only by grave motives, and it should be shown that the powder of ordinary composition was unable to produce the effects required of it. This is what has occurred with mining powder, since the explosive properties of azotised organic compounds have been recognized. But the two cases are very different.

With powders of ordinary proportions, but the physical properties of which have been rationally studied, it has been found possible to give to projectiles weighing more than twice the weight of a full sphere of the same calibre, velocities exceeding 600 metres; the charge about a third of the weight of the projectile. By introducing certain modifications into the cannon, and, perhaps, too, into the way of setting fire to the charge, we might be able, with a larger charge, to exceed 700 metres. We are stopped in this increase of velocity, however, by considerations of ballistics, and of the service of guns; in field pieces by the maximum weight to be given to the piece and its belongings; in pieces of position, but of large calibre, by the solidity of the piece itself. We see then, that the powder of ordinary proportions leaves a large enough margin for our utilizing all the progress which may be made in the art of construction of artillery *materiel.*

For the rest, the study of powders, in all countries, has always had for its final object to hinder the powder from giving in arms the maximum of effect it can give, by retarding its combustion, and increasing, thus, as well as by the mode of charging, the capacity of volume where the gases are developed. The result of all these experiments may be thus expressed; it is preferable, both from the ballistic point of view, and that of conservation of *materiel*, to obtain a velocity by increasing the charge of powder, rather than by forcing a less charge to burn under a greater tension.

These results have only been got by physical modifications of the powder; but one can see that a change of composition could only contribute to them, on condition of presenting a diminution in the total work contained in the new motor. If, then, profiting by the aid of thermo-chemical theories, we had to choose a motor for guns, the known oxygenated compounds of nitrogen, other than nitrates, would first have to be quite eliminated, and among the nitrates the one apparently most suitable would be nitrate of potash, not only because it is the only one which, producible in large quantity, allows conservation of the

powder, but also because it is the one that has liberated most heat in its formation, and so renders the powder the least violent (*brisante*).

THE ECONOMICAL LIMITS TO THE USE OF ROLLED GIRDERS.

From "The Engineer."

EXAMPLES of engineering construction, especially those of roofs, are not wanting in which a sectional area of less than 2 in. is composed of more than one bar or plate. In other words, this absurdly small sectional area as built up is a compound instead of a simple section. It can be readily understood that, insomuch as the compound or built-up section requires a certain number of rivets to unite the different bars or plates of which it is composed, and that as holes must be punched or drilled for these rivets, there is a corresponding loss of material incurred. This loss is directly proportionable to the difference between the gross and the net sectional area. For instance, if we take an angle iron 3 in. by 3¼ in., and suppose it riveted to the flanges and web of a solid-sided or plate girder by rivets ¾ in. diameter, its gross sectional area will be 2¾ in., while the net will amount to only 10 in., thus showing a loss of nearly 30 per cent. In this calculation the diameter of two rivets has been deducted, for although the rivets in the flanges and web can be designed so as to break joint in the drawing, yet when the wrappers are taken into account, and the joints, it would not be safe practically to suppose that only one rivet-hole would come in the same line of section, but allowance must be made for two. Compared at first sight with the built-up section, the rolled joist has the advantage of dispensing with the riveting necessary to connect the web and flanges, since these are rolled all in one piece, and there is consequently no loss of sectional area. It would be more correct to say there is no loss of material due to rivet holes, for it will be seen that there is in larger examples considerable loss of sectional area both in the web and flanges.

A rolled joist is essentialy a girder with parallel horizontal flanges, since in the process of rolling the depth cannot be altered. We are not putting any limits at present to the depth or the length of the joist, although practically the limits would be soon arrived at. Our object is to point out that were the capabilities of the rolling mill unlimited in this respect, there would nevertheless be a certain span and load beyond which the employment of rolled joists becomes wasteful of material. Besides the uniformity of depth which must prevail in a rolled girder, the sectional area must also be maintained constant, since neither the width of the flanges nor their thickness can be varied, nor the thickness of the web. So far as a span of twenty feet is concerned, or under, it is of no consequence whether any of these dimensions are varied or not; but when this span is surpassed some greater coincidence between the theoretical and actual sectional areas of the girder at different points becomes absolutely necessary if economy in construction is of any moment. Theory dictates that in every girder which is subject to the ordinary conditions attendant upon these structures, either the depth or the sectional area must vary. It is in many instances immaterial in which of these dimensions the alteration is made, but one or the other must undergo it. The depth may be maintained constant provided the sectional area is diminished towards the ends of the girders in proportion to the strain; or the sectional area may be maintained constant, or very nearly so, if the depth be decreased towards the same points. The fulfilment of the former conditions gives the correctly designed parallel girder, and of the latter the bowstring. Neither of these forms can be produced from the rolls. It is true—and the advocates for the employment of rolled joists lay great stress upon the assertion—that an unscientific approximation can be made to the former of these types, not by diminishing the sectional area towards the ends, but increasing it by the use of extra plates riveted to the flanges towards the cen-

tral part of the girder, which amounts to much the same thing. But, allowing that this increase of section can be obtained in this manner, the minimum or rolled section of the flange must still be constant, both in breadth and thickness. Moreover, when extra plates are riveted to the flanges in order to give an increased sectional area at the centre, the principle of the rolled joist is at once departed from, and it becomes, to all intents and purposes, a built-up girder, without possessing the advantages of that particular form.

It is not only in the flanges that a loss of metal occurs from the impossibility of varying their section, and also in consequence of their depth being uniform, but the web suffers as well. As the girder becomes longer so must its depth be increased, a condition which cannot be practically fulfilled without at the same time increasing its thickness. This latter dimension will be constant throughout the whole girder. Theoretically, with a uniformly distributed load, the strain upon the web of a girder at its centre is *nil*, and even with a rolling load of the same intensity per foot run its amount is not of much consequence. Rolled girders are more frequently employed to support uniformly distributed than moving loads. Consequently, the strain upon the web is nothing at the centre, and a maximum at the ends. The shearing strain at the ends is equal to one-half the total distributed load. Thus the sectional area of the web at the ends must be sufficient to resist this strain, and by the conditions of manufacture it must be constant throughout the girder, although theoretically the strain diminishes to zero at the centre. There is no need of pointing out the enormous loss of material which would occur in a girder of any pretensions to size, supporting a load of any consequence. This disproportion between the sectional area of the webs of rolled girders and the strains upon them must always remain, since the method which can be employed to vary the area of the flanges cannot be applied to the web. Theoretically, as the sectional area of the web must be proportioned to resist the maximum strain upon it, the loss of material in this respect is exactly 50 per cent. Practically it would not amount to quite so much as this, because there must of necessity be some material in the central portion of the web, but still the excess would be very considerable.

It will be conceded that the strongest girder is that which with a given weight of material will bear the greatest load under precisely similar conditions. Let us compare in this respect the rolled and the built-up girder, and as a datum to start from, let the span be 20 ft. and the depth 1 ft., which is not far from the limit of depth hitherto attained in the rolled section. Commencing with the flanges, it is obvious that since the net sectional area of both must be equal in either to withstand the same strain, the advantage lies on the side of the rolled girder, because the gross sectional area of its flanges is equal to the net area. There is no loss of material due to the connection of web and flanges. The built-up girder, on the contrary, is subject to a certain amount of loss due to the difference between the gross and net area of its flanges, and consequently the weight of material in the flanges must exceed that in those of the rolled girder in order to afford the same net sectional area. With a given net sectional area, therefore, the flanges of a rolled girder will be lighter than those of a built-up one. But, if the comparison be carried further, it will be found that what the built-up girder loses with regard to the flanges it will more than gain with respect to the web. In the example selected, taken from a trade circular, the thickness of the web of the rolled section is $\frac{9}{16}$ in., whereas in a built-up girder of the same area of flange and depth, $\frac{1}{4}$ in. is more than sufficient. Besides, the thickness of the web of a rolled girder must increase with even a very small increase of the depth, and must, moreover, be uniform throughout the entire girder; but this is not the case with the web of the built-up section. The thickness of the web of a plate girder, which is always in excess of the requirements of theory, need not be increased until the depth is nearly doubled. A few additional stiffeners are all that are necessary to give rigidity to the greater depth of the web.

In connection with the subject of the relative strength of the type of two girders under consideration of the same

total weight, it must not be lost sight of that the strength of a girder of any form does not depend exclusively upon the actual sectional area of either the flanges or the web, but is due in equal measure to the observance of the proper proportions between the span, the depth, and the breadth of flange. These nice adjustments are easily insured in the case of the built-up girder, but not in that of its rolled fellow. It is here that the former has an immense advantage over the latter, particularly when the dimension of the span exceeds 20 ft. The proper theoretical ratio between the various parts of a girder cannot be observed in those of the rolled form. Hence, in comparing a rolled and a built-up girder under the same conditions of loading and weight, the weight of the flanges of the latter can be decreased by increasing the depth without at the same time augmenting the weight of the girder in the same proportion. Briefly, the great difference between the two is that a built-up girder can be designed so that the dictates of theory can be very closely adhered to in practice, and a rolled girder cannot. The form and proportions of a built-up girder are the result of theory, those of the rolled section the result of practice. The exigencies of the manufacturing process virtually determine the relative proportions of a rolled girder. Some attempt is made to assimilate these to what theory would indicate as the correct proportions, but with very equivocal success. It is in fact not possible to roll a girder with a proper regard to these theoretical requirements.

Summing up the subject, it would appear that in the comparison we have instituted, when the span does not exceed from 10 ft. to 20 ft., a rolled girder will be cheaper than a built-up section, for although there may be a superfluity of metal in a part of it, yet the price per ton will be less than for built-up sections. When this limit is surpassed the weight of the built-up girder of the same span and depth will be slightly less than that of the rolled girder. This supposes the ratio of depth to span not to be that which is calculated to give the greatest amount of strength. If the built-up girder be correctly proportioned, so as to reduce the strains to a minimum, it will be cheaper than the riveted section for a span greater than that already alluded to. The riveting together of a couple of rolled girders longitudinally, so as to double the depth, is a handy expedient as a makeshift, but in complete defiance of all theory. The material in the two flanges, which is then concentrated in the middle of the web, is so much waste metal, since it is situated at or near the neutral axis of the whole girder, and its leverage for resisting strains is reduced to a minimum. Other ingenious combinations of rolled girders are sometimes made. For example, two or more are placed side by side and united by horizontal plates riveted over the top and bottom flanges. This arrangement possesses all the disadvantages of the old box girder, which is now obsolete. It is quite impossible to get at the inside after the plates are once put together, and the same remark applies to the combination of rolled joists with regard to the spaces between the parallel girders. While, under certain circumstances, and within certain limits, rolled girders are exceedingly well adapted for constructive purposes, and could be employed to advantage by engineers to a much greater extent than they are; yet, whenever a girder is required to fulfil certain conditions which admit of a theoretical adjustment of sectional area of strain, they will not be found economical. In a word, if a girder of small span is required to be merely adapted to a given load, one or other of the ordinary rolled sections will be found to be both convenient and economical. But if the span and load are of sufficient importance as to call for a design, the built-up girder, either rolled or open webbed, is the only proper type to adopt.

HERREN Behum and Wagner have recently published their measurements of the earth. According to them, the length of the polar axis is 12,712,136 metres; that of the maximum diameter being 12,756,588 metres, the minimum 12,752,701 metres. The circumference is on the shortest meridian 40,000,098, and on the longest 40,069,903 metres.

THE POLLUTION OF RIVERS.

From "The Journal of the Society of Arts."

An important conference was held last month by the Society of Arts on the subject of "The steps to be taken to ensure prompt and efficient measures for preventing the pollution of rivers." The views expressed and the discussions following are herewith given:

The Chairman, in opening the proceedings, said that the papers which had been circulated in the room describing the various methods proposed for dealing with the difficulty would be taken as read, and he therefore proposed to take the discussion in the following order: 1. Existing evils and necessity of remedy. 2. Separation of fæcal matters, manufacturing refuse, and house drainage from the rain-fall. 3. Methods of treating water-carried sewage so as to purify it before discharging it into rivers. To each of these points an hour would be allotted.

Mr. J. Chalmers Morton (one of the Rivers Pollution Commissioners) submitted that processes having been already pointed out, and being well known by which filthy water can be cleansed, and by which therefore river pollution, in almost all its forms, can be prevented, it was no longer a solution of the once inscrutable problem that was required; it was a plain and workable law which shall forbid it that was needed. Law no doubt already existed for the abatement of river nuisances, so that if any one be aggrieved he has his remedy at present, and if he has a nature tough enough, purse and patience large enough, he may even now obtain the injunction he desires. But the practical value of the existing law may be safely gathered from the existing condition of our rivers. The existing law was virtually inoperative, and it was to the enactment of an efficient law that all our attention should be now given. The existing failure of the law against river pollution was owing partly to the costliness of its processes, but mainly to the indefiniteness of the offence which it is desired to prevent. He had always understood that a plain and unmistakable definition of a nuisance or offence was the very first step to be taken in any attempt to forbid it or abate it, and therefore he heartily hoped that this conference might see its way to the urgent and confident recommendation of the enactment of unmistakable standards of impurity, below which all liquid discharges into water courses shall be forbidden, as an essential part of any serviceable legislation on this subject. Without them it might not be always impossible to obtain a conviction; but he said that without them it was impossible that justice should invariably be done, for these standards were as necessary for the protection of the innocent as for the easy conviction of the guilty. At present, if you go before a court with your complaint in general terms of the nuisance by which you are aggrieved, you are certain to be met by evidence, also in general terms, that the thing is not so bad as you declared it, or that there is really no nuisance at all, or that if there be any discomfort it is as nothing compared with the tenfold injury which would be inflicted on one hundredfold the number of sufferers if any injunction should be issued; and what was a distracted jury, or even a clear-sighted judge, to do for either complainant or defendant in the face of contradictory evidence, both lay and scientific, so long as both are allowed all the resources of the English language with which to attack or defend? What was wanted was a set of standards to which the case could be at once referred with no possibility of ambiguity or uncertainty as the result of the reference. Of course it was necessary that these standards be most carefully fixed, so that, in the words of the Royal Commission, "there be no serious injury to the processes and manufactures concerned." As regards the standards which have been recommended in the reports of the Rivers Commission, he, though not professionally a chemist, had felt at liberty to sign the recommendation that these standards be enacted, because, having compared with them the analysis of the effluent waters from various remedial processes, he was able to say

that these standards were extremely lenient. It might surprise any gentleman who looks on this subject from the manufacturer's point of view to hear that the filthy Irwell water itself does not offend the standards of pollution of which we desire the enactment. It does not contain .2 of organic carbon nor .3 of organic nitrogen in solution in 100,000 parts. Of course it has been polluted by the access of drainage much filthier than itself, so that if these standards were enacted they would act beneficially on the Irwell; but the fact that this filthy river does not itself offend them is proof of their leniency. It might be thought a whimsical, or even fantastical thing to make, in an Act of Parliament, .0003 per cent. of organic nitrogen the definition of an offence; but we had a precedent for that kind of definition with the Alkali act; and he presumed that Dr. Lyon Playfair could ascertain and declare the presence of .3 of organic nitrogen in 100,000 parts of water, if not with as much facility, at least with as much confidence and certainty as that which he would feel, after counting hands, in declaring the minority, if any, which is prepared to defend legislation against offence without any definition of the offence it is intended to forbid. Lastly, no one had ever thought of putting these standards in the hands of the common informer. They must of course be administered by competent men appointed for the purpose. But to this, having already exhausted his allotted time, he would only advert. He earnestly desired that as one result of this conference some confident and urgent declaration might be laid before the proper Government department that the enactment of standards of forbidden pollution was essential to efficient legislation on this subject.

Major-General Scott, C. B., quite concurred in the view of the last speaker, that a standard of purity was essentially necessary before legislation could be attempted. But the principal question to be discussed would be what that standard should be. He believed that ultimately they would come to the only mode by which water when once foul could be purified, and that was either by using it in irrigation or by earth filtration. But while believing this, he also thought it would be very impolitic at the present moment for Government to legislate in such a way as to oblige every town to take up one of those two systems. In the first place land was in many places difficult to acquire, and in the next people objected to having a large amount of sodden soil in the neighborhood of their dwellings. Above all, you could not get any body of Englishmen to enforce upon landowners the necessity of having such saturated ground in their immediate neighborhood. This had been proved in the case of Birmingham. In that case almost every man who had a knowledge of the sewage question was invited to give his opinion; all the leading chemists, engineers, and agriculturists stated their views on the subject, and ultimately it was resolved to bring forward a scheme by which the separation of the solid from the liquid sewage was to be supplemented by irrigation and filtration. There was no doubt in the mind of any reasonable man that no better system than this could be proposed, but what was the result? After the bill had been approved by a select committee of the House it was thrown out, simply on the representations of two land owners principally affected by it, that it would be an injustice to them. At the present time therefore, you could not carry out complete legislation if it were attempted, and the question arose to what extent should it go. To his mind, the matter was very clear, and he would beg to read a few words written by the Sewage of Towns Commissioners, fifteen or sixteen years ago. They said "that by far the greater part of the solid matter held in suspension in water was readily deposited in rivers, covering the banks with mud and permanently raising the beds, gradually destroying the scouring power of the water, partially silting them up; and in some instances these deposits had accumulated to such extent as to impede the navigation, and render the surrounding country subject to floods, entailing a vast expenditure in periodical cleansing. And however the appearance of the water might be improved after these deposits had taken place, yet the deposited matters lay in the bed of the current under conditions favorable to putrefaction; so that when the foul mud was disturbed during the prevalence of rain or floods it sent forth effluvia very offensive

to the surrounding district." Here then, it was plain that the chief evil arising from the flow of sewage into rivers was attributed to the solid matter, and the Commissioners went on to state that this "might be obviated by simply arresting the solid matter in suspension in the liquid." Inasmuch as the Legislature itself had been instrumental in bringing about the present state of things, he thought it would be very hard on towns to oblige them all, and at once, to carry their sewage water to that degree of perfection which would be implied by insisting on irrigation or careful filtration. So far however as the solids were concerned, the remedy was easy enough. It would not press hard on municipalities to compel them to keep these offensive matters out of rivers. Fifteen years ago the Sewage of Towns Commissioners reported that "the more the subject had been investigated the more convincing was the evidence that there was no town which might not, with reasonable care, and at a moderate cost, greatly mitigate the existing evils, if not wholly remove them," and their conclusion was, "in the absence of means for applying sewage to land, the modes of precipitation at command did offer remedial measures of a very satisfactory character." If that were the case, why were we at the present day still in the same condition as before, with almost every town in the kingdom casting its solid sewage matters into the rivers? It had arisen because we had in the first instance aimed too high. He thought the last degree of perfection ought ultimately to be insisted upon, but at the present moment there were so many corporate towns on the banks of rivers, contributing to their pollution, that until they could all be brought to one point, it would be very unfair that one town should be picked out and made to purify its sewage perfectly, while others were still polluting these rivers. During the last three years he had a great deal to do with town councils and had seen many of their difficulties, and this much he thought might be insisted upon, that they should remove the solids from the liquids before the latter flowed into the river, and a graduated scale might easily be devised, insisting that the amount of solid thrown into rivers should not bear more than a certain proportion to the volume of water. If that much were done, more would be sure to follow, because they could not arrest the solids without creating some degree of nuisance which would necessitate the application of deodorization. Immediately that was attempted it would be necessary to use some precipitate, and then the solids might be much more perfectly removed. One-half of dissolved organic nitrogen would also be removed by precipitation, and the whole operation conducted in an inoffensive manner. The first step to be taken therefore, in his opinion, was to insist that only a certain amount of solid per gallon of sewage be allowed to pass into a stream, and the next stage would be that deodorization should be employed. When they got to that point, it might be a question in what cases further purification should be effected by earth filtration or irrigation, and, inasmuch as precipitation, or at least subsidence, was a necessary preliminary to these operations, manifestly the steps he recommended were in the right direction, and would make further legislation easier.

Mr. John Thom, speaking as a polluter of water, did not believe that any class of the community would be more benefited by legislation on this subject than polluters of water themselves. He did not speak from any theoretical notions, but from his own experience. There had been plenty of law, but there was as yet so little certainty as to how it might be applied in any given case, that the great majority of manufacturers all stood in danger both from those below and those above them on the stream. They might be prosecuted by any one below them for a nuisance, while any one above them might set up a manufactory which would do them positive harm. If they went to the most eminent lawyers for advice they would get different opinions as to what would be the result of the proceedings. About twenty-two years ago the firm with which he was connected had a lawsuit with regard to a pollution they sent down, and which was said to be doing great damage. They lost the case, but they gained much more than it cost them from having no more pollution of the same kind from those above, in fact, it was stopped in a day, showing that any legislation preventing pollution

might very readily be carried out. About eighteen years ago he commenced keeping his own pollution out of the stream, but he was immediately served with a notice from the legal adviser of his landlord to refrain from any such attempts, as it was endangering his water rights and privileges. The landlord claimed to foul the stream, and in his lease there was a clause of surrender if those rights were endangered. This showed the necessity for legislation before means could be used for keeping pollutions out of the rivers. Again, the water generally came down to his works quite black to the amount of between two and three millions of gallons daily; and from careful experiments he had ascertained that one part of this black dye water would make 10,000 parts unfit for his use, so that one part being put in by a person above him compelled him to purify 10,000 parts of water; yet from a letter which he held in his hand it appeared that the manufacturer above could keep that black dye out of the water with the greatest ease, and at a merely nominal cost, in fact, he believed it could be done with a profit. Legislation, therefore, in such a case would only give fair play to all manufacturers or polluters of water. Again, on the stream above him there were large works in course of erection, which must of necessity foul the water, and from the absence of any law upon the subject those who were erecting those works did not know what to do. They put them up at haphazard, subject to prosecution if they fouled the water, and he had no hesitation in saying that it would take from 3 to 7 per cent. on the outlay on that plant to settle their legal rights, but he was equally satisfied that with proper legislation on the subject only a half per cent. would be required to enable them to keep all foul matters out of the stream, and thus avoid doing any mischief to every one between themselves and the sea.

Sir Robert Torrens, who represented the Conservators of the River Dart, said the special grievance in the district from which he came arose from the constant starting of small mines, nine-tenths of which were got up simply for stock-jobbing purposes, not really for mining. The speculators in these schemes set up works merely to sell the mines, and the earth washed out from the crushed ores was allowed to flow into the rivers in all directions. The law enabled the Conservators to interfere and stop that process if they could show that this earthy matter actually poisoned the fish, but they were utterly powerless to check it, if, as was generally the case, it did not poison the fish, but simply deterred the salmon from coming up the rivers, and spoiled the spawning beds by depositing mud where nature had placed sand and gravel, on which alone salmon would deposit their ova. The question then arose, what means could be suggested for remedying this grievance. It appeared to him very simple, and they had practical proof of their efficiency. In the Black Forest of Germany, where mining of various kinds was carried on, before the water used in washing ores was allowed to return into the stream, it had to be passed through settling tanks, in which all the mud was deposited. The water flowed through furze bushes and things of that kind, very inexpensive, and the deposit was cleared out periodically when the tanks got too full. In almost all the cases he had in his mind in Devonshire, such tanks might be put up at a very trifling cost indeed. The managing engineer of a mine above Ashburton, on the River Dart, stated that for £150 he could put up a tank of that kind, but he demanded that the Conservators should pay the cost. Inasmuch, however, as they would have no guarantee that it would be erected, or that the speculators might not cease to use it if they paid the money, of course it could not be done. He might mention another case of a mine which had been tried once or twice, and had been shut up, having scarcely any minerals in it, but it had lately been opened again in another name in order to delude the public; the water which had lodged in it for years was pumped out, and the consequence was that it killed all the fish in the stream that flowed through Ashburton. Another mine had been started close to his own place, when the stream, which had been beautifully clear, assumed the appearance of red ink. Unfortunately the law was so doubtful, and the machinery so costly, as practically to prohibit the Conservators taking any steps to remedy this grievance. He concurred in what had fallen from a preceding speaker, that it would not be well to attempt a

very large measure of relief until public opinion was sufficiently aroused upon the subject, but if a moderate measure were proposed it might perhaps be carried, such for instance, as one which would compel any parties starting a mine to deposit £500 or £1,000 as a guarantee that before turning the water into the stream they would cause it to be filtered and purified. This was a most vital question affecting the whole population, though unhappily a very small portion indeed of that population was at all alive to its importance. On the other hand there was a very compact and powerful body interested, or imagining themselves interested in opposing any such effort as they were assembled to discuss, and he should like to see subscriptions got up for the purpose of circulating information on the subject, and so instructing the public mind, for until that was done he believed it would be utterly hopeless for any private member, and almost for any Government, to attempt to carry a comprehensive measure in the face of the manufacturing and mining interests in the House of Commons. He had stood three contested elections, and had never been questioned on the subject, nor did he remember any case in which a candidate had been required to state what he would do on this most important question. He, therefore, thought the first necessity was to create such a pressure of public opinion as would lead to something being done at the next election to promote efficient legislation.

Sir John Murray desired to make a few remarks on some of the rivers in which he was deeply interested. He would first call attention to a small stream called the Sherborne, not far from Coventry, known in years past as one of the dirtiest and foulest streams in the kingdom. The sewage of Coventry ran into it, but since this had been treated in tanks, which had been built for the defecation of the sewage, it had a very different appearance. Formerly for two miles down it was almost impossible to inhale the atmosphere in its neighborhood without feeling the bad effects, and as for fish they existed but a very short time in it. How they got into the stream nobody knew, but probably they were brought in from other quarters at times of flood. Matters were very different now, for he had letters in his possession from gentlemen residing on the banks, stating that the water was exceedingly pure, and that the fish were rapidly increasing in numbers. Now, if a simple process such as that adopted at Coventry —the use of sulphate of alumina in conjunction with lime—was so successful in treating the sewage of a town of 40,000 inhabitants, the daily sewage being two millions of gallons, he thought every town and village might be required to adopt similar means, and he understood that this method yielded an effluent whose purity was above the required standard. This question was one of vital consequence to the inhabitants of the whole of Great Britain. The first consideration was certainly sanitary, the object being to obtain pure air and water; the second was agricultural, for why should they throw away a valuable manure estimated to be worth two millions per annum? and the third, which came home more to himself living near the banks of some rivers in the south of Scotland, had reference to the question of fishing. The Tweed Fishery Laws had lately been the subject of investigation, and it appeared that heavy penalties, and even imprisonment had been inflicted for years past on poor fishermen who killed a smolt or small salmon, yet at the same time corporations on the banks of those streams were allowed to destroy the fish with impunity. This certainly was not a state of things which ought to be allowed.

Major-General Synge said that since he came into the room the question had occurred to his mind why anybody objected to the pollution of rivers, and why had such a practice come into such universal existence if it deserved to meet with the unmitigated reprobation of every intelligent being living near a stream. But really they had met to try and put a stop to what might at any moment prove the most desolating plague that ever afflicted the globe. Then what position did they individually occupy so long as they contributed to the propagation of the evil? The reply suggested itself to his mind that the prelude to the abuse of anything was the ignorance of its proper use, and if the objects for which water was given to mankind were properly appreciated, he thought it would be impossible for two persons to state, as he had

heard in an assembly of a similar kind to the present, that water was a thing which, under no circumstances, ought to be drunk, and that the proper thing to do with every stream was to turn your back upon it and make it a vehicle for the gravest abuses. If the value and proper use of water was appreciated, it would not be necessary to devise any elaborate or scientific process. The first thing to be borne in mind was the individual duty of every man to himself and to his neighbor; but secondly, this duty must always be taken in connection with the possibility of carrying it out, and they must therefore consider whether it was really impossible to maintain the purity of water. There was much to be said in palliation of the existing system, seeing the elaborate, ingenious, and complicated machinery which had been devised for dealing with it. He believed, however, the only sound advice with reference to turning sewage into rivers was that given some years ago in *Punch*, though on a very different subject, namely, "Don't." He disliked compulsory action, for he thought no man had a right to take his neighbor by the throat and compel him to do anything, but it would be quite possible, and perhaps a popular novelty, to go back to the Decalogue and say, You shall not murder by inflicting on your neighbor the poisonous outcome of your own person; you shall not make it a difficulty to know whether your linen has been washed in pure water, or whether every shirt you wear shall not be a source of fresh danger, and every opening you make in your room an additional means of poisoning your neighbor. He should simply take this ground. If a man chose to do anything on his own premises, it should not injure his neighbor. The details of how this might be carried out were embodied in some of the proposals which had been printed. But if they went on this simple basis of the duty of using water, and not corrupting it, and then went on to exclude all putrescible matters, they would soon arrive at a practical result.

Mr. John Evans, F. R. S., suggested that it would have been better if a fourth subject had been added with regard to the legislation to be proposed. There could be no doubt that some remedy was necessary for existing evils, but his difficulty was how that remedy should be applied so as not to act unfairly on existing classes, more especially upon manufacturers, considering that the Society, under whose auspices they were gathered, was established for the promotion of arts, manufactures, and commerce. The subject divided itself into two heads; namely, the pollutions caused by fæcal matters, and those resulting from mineral matters, the produce of ordinary manufactures. If rivers were purified to that extent that fæcal matters were excluded from them, it would be a much more simple matter to deal with the matters arising from the manufactories, but it was evident to him that though it might be desirable to have some fixed tests established, those tests should not be of precisely the same nature in all cases, but that some modification should be allowed in respect of certain classes of manufactories, and that provision should be made for those with whom it was a matter of almost absolute impossibility to carry out the remedies which might be suggested. It was all very well to say that men should be compelled to send water into a river in a state of purity, which should comply with certain tests; but in many cases where the works were situated on a limited portion of ground, or on particular levels, it became almost impossible to carry on any purifying process on a large scale. Suggestions had been made for a series of ponds, or catch pits, but how on earth was a man, limited in his ground, to adopt that system? Therefore, any measures of a compulsory nature ought to be accompanied by special provisions enabling a man to obtain the necessary means of carrying them out. If a manufacturer were driven into adopting a large system of irrigation, a man below him might bring an action against him for diverting the stream, while if he adopted a system of evaporation, he was liable to be prosecuted for a nuisance. It was by no means so simple a process that any one given plan would be applicable to all circumstances, and though he agreed that there should be some fixed standards, they should be in the first instance of the mildest character. There ought to be variations allowed in the case of particular trades and manufactures, with liberty to the public authorities to abstain from calling on any particular manufac-

turer to comply with them, if there were no sign of danger resulting to the stream from his works being upon it. It was not every river which was intended to be potable, and there were always considerable differences arising from the proportion between the volume of the stream and of that which flowed into it; thus a drain carrying 10 gallons a minute into a large river did not effect any material mischief, while if it discharged into a small stream it would seriously injure the purity of the water. Tidal rivers again stood on quite a different footing to others.

Sir Joseph Heron said he would propose a resolution, as he had no objection to throw upon the Government the responsibility of finding out what legislation was practicable, and he thought they could not err in bringing it under their notice. It was no use abusing local authorities for the state of their rivers so long as they were utterly powerless to act in the matter. In Manchester, however, he believed the Irwell was in a better state when it passed out of Manchester than when it came in. They had an enormous supply of water, and such an immense quantity went into the sewers that it diluted the sewage to such a large extent, as compared with the state in which sewage passed into the river above, as to considerably improve the state of the river. He protested against the abominable system of introducing water-closets into every town and village, and turning all the refuse from these closets into the sewers. He considered this was beginning at the wrong end, though unfortunately the Government had, under certain influences, coerced local bodies into the introduction of this system. The resolution he had to propose was: "That this meeting, being satisfied that it is necessary to improve the foul state of the rivers in this country, and that legislation on the subject is required, requests the Council of the Society of Arts to urge this necessity on the attention of her Majesty's Government by deputation or otherwise." He did not think it would be of much use, as suggested, to circulate pamphlets, which would only be thrown into the waste paper basket; but the moment the Government dealt with the subject, and proposed legislation, the attention of the country would be drawn to it, and some good might be done.

Sir John Murray seconded the resolution, which was at once carried unanimously.

The Chairman said they must now consider the second branch of the subject, namely, "Separation of fæcal matters, manufacturing refuse, and house drainage from the rainfall," and he would first call upon Captain Liernur, who had made some important experiments at Amsterdam and other towns in Holland, to address the meeting.

Capt. Liernur said the method of using sewers so as to carry off the rainfall, and also to remove the fæcal and other putrescible matter, was without doubt attended with many serious drawbacks. That matter was very often, if not always, the carrier of organisms having infectious properties, which were not kept in the sewer, but were apt to pollute both the air and soil of the town. The air was polluted from ventilating the sewer itself, and escaped at every rise of the sewage as affected by the rainfall. Whenever it rained after several days of dry weather, the polluting elements were passed through the pores of the brickwork by simple hydraulic pressure, and when this subsoil water rose, a stratum of air equal to the rise of water was pushed upwards, carrying these infectious elements with it. Hence, so long as infectious matter was conveyed by means of water, and carried through porous conduits which were in contact with the atmosphere, there could be no other result but that both the air and soil became contaminated with the seeds of disease. Many sewage engineers thought it was not unhealthy to live in towns the soil of which was polluted with excrement, and hence they advocated the use of rain-water sewers ventilated as much as possible. He did not know upon what hypothesis they based their theory, and he could not but think that the great increase of several kinds of zymotic diseases in towns served on this principle tended very little to support it. At any rate, Continental authorities on sanitary matters were of a different opinion; they insisted on the conveyance of any matter which might carry infection through conduits from which the escape of any fluid or any gas was absolutely impossible, and

also on absolute cessation of all fluctuation in the level of the subsoil water. Hence rain-water sewers should not act as drains for waste water, and fæcal matters and household refuse should be removed separately by air-tight iron pipes, or some similar contrivance. This was also demanded by the danger created outside towns; namely, the pollution produced where sewage was discharged. The cleansing of sewage by precipitation and filtration was known to be practically impossible; nor had irrigation upon the whole been much more successful, but had shown itself only a serious additional expense, besides being a danger to the public health; hence most engineers had preferred recently to discharge sewage into the sea wherever there was a chance of so doing, and did not hesitate to construct miles of culverts for that purpose, rather than involve towns in the troubles and lawsuits which often arose in connection with sewage farming. On the other hand there was no technical or financial difficulty in the separate removal of putrescible matter, or any danger of polluting the air or soil with it. This had been proved by the works constructed by himself. They consisted of a net-work of hermetically closed iron pipes in connection with a stationary pumping engine. This collected the contents of both privy-closets and kitchen sinks, the motive power being air instead of water. This system did not prevent the use of water-closets, provided they only used water enough to keep the basin clean, for which experience showed one quart was sufficient when the closet was properly constructed. Water-closets, however, were not necessary on sanitary or æsthetic grounds. Privy closets had been constructed for the poorer classes, in which no water was employed at all, and they appeared to give every satisfaction, and it was certain that the offensive matter could be removed without the enormous dilution, which, by the method of water carriage, made its utilization for farming purposes almost impossible. The matter in question could be transported for use in the wet form as collected, or be converted into a dry substance by evaporation in vacuum pans. In the first case its value to the farmer was 3s. 6d., and in the latter from 8s. to 12s. 6d. per head per annum. There was no other method by which the utilization of sewage could become profitable, for generally speaking the disposal of the matter was as much an expense as its removal, and hence the sewage of towns involved a considerable increase of taxation, which led to an increase of house rent, and resulted in a crowding together of the working classes in still smaller rooms, and in raising the price of all necessaries of life. These resultants, however, were the reverse of sanitary, and it appeared very questionable if the sewage works, at the cost of the comfort of the poor, were really sanitary improvements at all. The separate method avoided this sort of danger; it made the collection and disposal of putrescible matters a source of profit, both possible and practicable, the result being that a town could be sewered without polluting either the soil, the air, or the stream, and without increasing taxation. This could never be effected by the pail system.

The Rev. Henry Moule said the evils of pollution and waste were the necessary results of the daily accumulation of putrefying and putrefied matter in drains, sewers, and cesspools; and to deal with such intractable substances *en masse* was impossible. This serious evil must be traced and dealt with in detail, which by the water system was impracticable. A general system, however, of earth-closets was perfectly feasible, and to such an extent that the cleansing of towns and villages would in many cases be not a matter of expense, but of positive gain. By this system that substance was removed from the drains and sewers which was most offensive, and which presented the greatest difficulty to deal with; and thus the necessity of flushing was avoided, which reduced the quantity of water required by five-sixths. The remaining sixth could be dealt with quite easily, especially if slops were removed from the sink-water, which could be carried off by small drains. The contents of the vaults need not be carried away oftener than once in three months, and if the product were only worth 10s. per ton, it would, from a town of 25,000 inhabitants, produce a revenue of £10,000 per annum. The Rev. gentleman further proceeded to narrate the financial results which might be obtained by the application of sewage to garden ground, and the general effects produced by the use of the earth-closet

system, the details of which may be found in his printed communication.

Prof. Wanklyn wished to say a word with reference to the question of standards. The first speaker had stated that .003 of a part per cent. of organic nitrogen was sufficient to condemn an effluent, and moreover that chemists were perfectly able to determine that amount. Now he wished to state that there was no process known to chemists by which the organic nitrogen could be determined. There was one process which he believed was only employed by one chemist of eminence, and it yielded an error of 1,000 per cent. on the substance on which it was applied, which was perfectly absurd. Thus if the water yielded an impurity of .5, the experimental error was 50 or 1,000 per cent. There were, however, indirect means of ascertaining what would be implied by three parts of organic nitrogen per 100,000 parts of water, or .003 per cent., and it would no doubt surprise some gentlemen to be informed that such a standard would admit the foulest sewage in the country into any river, and thus any legislation which would enact such a standard would license the passage of the filthiest impurities into our streams. He was not in favor of what were called chemical standards, to be applied to effluents, and the only one he would be inclined to adopt would be transparency. He agreed with General Scott that the only practical enactment would be to insure that a perfectly clear liquid should flow into the rivers.

Mr. Baldwin Latham, speaking as an engineer, thought it very desirable to separate sewage matters from ordinary rainfall, but it was sometimes a question of very great difficulty when you came to apply it. For instance, he might take as a typical town one of those in the Potteries which had been sewered on the separate plan. If the rainfalls were excluded, what with the nature of the materials used in macadamizing the roads, the amount of filth that accumulated upon them with the constant practice of the lower classes of the population of going to the street door and throwing out the whole of their slops on to the highway, all tended very materially with the small rainfall to produce a liquid quite equal in polluting effect to the strongest sewage you could deal with. On that ground, although this arrangement had been adopted in two such towns by the Duke of Sutherland—who had come forward as the largest landed proprietor of the neighborhood to assist them in getting out of their difficulties with regard to this question, thus setting a good example to other land-owners—it had been found absolutely necessary to make a connection between the rainfall sewers and the sewers proper, so that when there was a small amount of rainfall passing through the sewers a connection might be made between one series and the other, and the small amount of rainfall might pass into the sewage proper; whereas when the flow increased and the volume of water was larger, the whole of that water would pass away to the natural streams of the district. There were, however, many districts more happily situated, such as those governed by rural sanitary boards, who had nothing to do with the drainage of the roads or the making of gulleys, and who could therefore carry out their works much more cheaply than had been done by authorities acting under the jurisdiction of local boards. This question of the separation of fæcal matters from rainfall to a certain extent opened out the question, what was the best system to be adopted for the collection of fæcal matters, whether they were to be passed into the sewers or dealt with in any other way? As a general rule, he thought, in large towns, where there was an abundance of water, the water-closet system would always commend itself for adoption, because, from long experience on this question, it had been shown by the River Pollution Commissioners that from the inquiries they had made the amount of polluting matter contributed by water-closets was not materially in excess of that where the ordinary middenstead or dry system was in use. They also knew that in some towns which had been put under the system of collecting fæcal matter directly from houses, the amount collected did not equal more than one-tenth of the whole produced, so that nine-tenths must find its way ultimately into the sewers. There was also this advantage, that where you had water brought into towns for various purposes, it could be made use of for carrying away this matter immediately from the premises, for that was the im-

portant point in a sanitary point of view; and no dry system whatever had been introduced which did not render it necessary for it to be kept about for some time. He was not going to say there was no value in the earth-closet system, for he had himself recommended sanitary authorities to adopt it, and thought it a very valuable appliance in some positions. Capt. Liernur's system also had much to commend it, and it was certainly far preferable to that horrid system of pails which was now adopted in many manufacturing towns in Lancashire; to carry such disgusting matter through the habitations of the people was an abomination; the very sight of the process was disgusting to any one, more especially if the removal was neglected for a short time. The positive abomination of the apparatus was such, and the interval for collection was so great, that an accidental visitor to an establishment quite put out the ordinary calculation, and rendered what might be otherwise a little unpleasant, an intolerable nuisance. Captain Liernur's system had this advantage, that it collected the whole of the fæcal matter, but did not depend on manual labor. It did not invade the privacy of the dwelling, being effected by special pumping machinery, and consequently the work could be performed much more cheaply. With regard to the sewage of Manchester, he believed the analysis of it, taking it with all its fæcal matter kept out of it, was more foul than that of many water-closet towns. He knew that towns had many deficiencies to contend with, but he believed the separation of fæcal matter from rainfall was of great importance, and should be insisted upon in almost every instance.

Mr. Charles James Wahab, referring to the North Esk, a small river in Midlothian, said there were nine paper mills, containing sixteen paper machines, situated upon it, and consequently a very large amount of polluted water was discharged into the river. The stream was small, only containing below the paper mills 3,500 cubic feet a minute in the summer, or 31½ million gallons in a day. The impurity was equal to 14.5 grains per gallon, or a total equal to 29 tons 2 cwt. daily. Above the mills this stream contained an impurity of 7.6 per gallon, which, upon the same quantity of water, would amount to 15 tons 5 cwt., so that the added impurity in passing the mills amounted to 13 tons 13 cwt. It had been found, however, by numerous carefully conducted experiments, that only 6.4 grains per gallon were added from all the paper mills, so that there remained a quantity of 7 tons 13 cwt. from other causes. He had only to add that this stream had upon its banks, besides these paper mills, a number of little villages and gentlemen's houses, and it was his opinion that a great quantity of this impurity, which was unaccounted for, arose from the sewage of these houses and villages. This showed the great importance of treating sewage in a different way to manufacturing refuse. It had always appeared to him extremely hard on manufacturers that they should be obliged to purify their discharges and brought into Court as contaminators of rivers, while riparian proprietors and the agricultural labor of the country were evidently to blame to almost the same extent.

Mr. Charles Elcock thought the object of the meeting should be practical, and that it would do well to take into consideration the question of the propriety of separating all fæcal matter and manufacturing refuse from the rainfall, and, if possible, to decide whether it was desirable or not. It appeared to him it was essential it should be done, if the rivers were to be maintained in that degree of purity which they ought to possess. It was said that the amount of impurity added to rivers from water-closets was very small, and this was brought forward as an argument why excreta of this kind should be allowed to go into them. But if it added anything to the already existing impurities in the sewage proper of a town, it appeared certain such a discharge ought not to be allowed. The next question was as to the most suitable means by which the fæcal matter could be kept out of sewers. There was no doubt that so long as towns existed, sewers must exist, but that fæcal matters should be allowed to go into them no sane man would admit. No one need go further than Over Darwen to see the effect of a little fæcal matter getting into a sewer, for any gentleman who during the last month had walked through the streets and happened inadvertently to get over one of the

gratings would have perceived such a stench, as, to use a common expression, must be experienced to be appreciated. What then could be done to get rid of the night-soil instead of passing it into the sewers? They had heard a very elegant term used for the receptacles, as they were called in Manchester, in which they were collected, but wherever the system of collecting the night soil in pails, whether wooden or galvanized, had been introduced, it invariably tended to a decrease in the death rate and in the prevalence of typhoid fever, which was a most important item to take into consideration. He contended under proper arrangements these receptacles were not objectionable, and he had had considerable experience in dealing with them. In fact, there might be a pile of them in the room reaching up to the ceiling, and no one would be aware of it if his eyes were shut. It had not, however, been sufficiently considered that night-soil was not the only thing to be got rid of. There were other nuisances in towns quite as great, though engineers years ago, not having their attention sufficiently directed to the matter, took it into their heads that getting rid of the night-soil was the one thing for them to do, and consequently the water-closet system was invented, than which a more ingenious machinery could not be suggested for the introduction of poison into houses, and Acts of Parliament were brought into force to compel their adoption. Happily in Manchester there was a different state of things, and now no house was allowed to be built which had not in connection with it at least one open dry closet outside the house. It would be found on inquiry that the refuse from houses, streets, abattoirs, and many other places, was quite as injurious as the night-soil nuisance, although it did not make itself so immediately apparent, and this refuse of streets and houses had been found, when properly treated, to furnish the most effectual means of preventing these receptacles becoming in any way objectionable. This was done by simply converting this street and house refuse into the most powerful deodorant known—viz., charcoal—and a means was thus provided for deodorizing the foulest collection from any cesspool, and converting it into a sweet and wholesome mass.

Mr. Alderman Taylor (Rochdale) having heard one or two depreciatory remarks of the pail system, wished to add his testimony to its efficiency, being quite satisfied that in many Yorkshire and Lancashire towns it would be impossible to remove the refuse matter without some such system. Many gentlemen spoke of it, and even wrote about it, who had never seen it in operation, or tested it in any way, and whose statements therefore were obviously of no value. The manufacture of night-soil into manure had been spoken of as desirable; it had been adopted at Rochdale some years, and they would shortly be able to prove, not only that it was desirable, but also profitable. When that was the case he thought it was a very serious matter for all towns to consider, because many of them were short of a good water supply; and it would therefore be very desirable to avoid using water, if not absolutely necessary, for carrying away the refuse fæcal matter, as it was supposed, in the cheapest way. He however believed that that so-called cheapest way was the dearest that could be devised, for you not only spent a large sum in water, but diminished the value of the manure amazingly. He might say also that he was a strong advocate for irrigation, but the difficulty they had in the North was in getting land at anything like a reasonable price. Unfortunately the landowners tried to put upon them a kind of black mail, and they were obliged to give three or four times its natural value for any land to be used for such purposes.

Mr. Adam Scott desired to correct a possible misconception arising from what Mr. Latham had said with regard to Captain Liernur's system. He seemed to think that that system only effected the removal of fæcal matter, but it also removed the house slops and other matter which was quite as important—viz., the fatty sedimentary deposits from kitchen sinks which were practically of the same nature, though they had not passed through the human body, and therefore were not so far on the road to putrefaction—and the other various organic matters in solution which caused the great difficulty in the sewage question. The muddy detritus which found its way into the street sewers was of a very similar character, but Captain Liernur did not

allow any of that mud to collect, as, if time had allowed, he could easily have shown.

THE CHAIRMAN said the question of separating fæcal matter and manufacturing refuse from the rainfall was a most important one, but as there were so many opinions upon it, and so many methods under trial, the meeting would probably agree with him that it was not desirable to pass any resolution upon it. They would therefore pass to the consideration of the third branch of the subject, "Methods of treating water-carried sewage so as to purify it before discharging into rivers."

MR. C. RAWSON said he was naturally a great believer in one process of treating sewage, viz., the A B C, being the managing director of the company, but while advocating the advantages of his own system, he should be sorry to say a word against any other. He contended that in any system of precipitation there were four points which should be carefully attended to: one, that the effluent water should be fit to go into the river; second, that in the treatment of the sewage proper no nuisance whatever should be created; third, that there should be no chemical used which should in any way deteriorate or injure the manurial qualities of the sewage, for when they considered the extreme care with which farmers collected all the manure they got for use upon their fields, it was rather a reflection upon the science of England that at the present moment they were pouring into the rivers and losing by far the most valuable manurial material which could be used; fourth—and this was perhaps the most important in the eyes of many corporations—that the manurial produce should be valuable and should pay the whole expense of treating the sewage. He believed that the A B C process in every way fulfilled these four requirements. He would not stay to explain the process at present, but he had brought forward the evidence of independent officials bearing testimony to its success in the four points he had mentioned. His experience had led him to believe that there was not a single product of any manufacture or dye works which might not flow into the sewer and be treated by the A B C process as easily as the sewage itself, and, in fact, sometimes these constituents actually assisted the precipitation. At Leeds the sewage came down charged with most extraordinary dyes, yet after being treated by the A B C process, the effluent water formed a beautifully clear white cascade from the end of the works, which astonished everybody who saw it.

MR. CHARLES JONES said he had intended to offer a remark or two on the separate system of carriage, but he would only add, with reference to that point, in addition to what had been said by Mr. Latham, that he wished that the Government would give some help on the question, and if any deputation were appointed he hoped they would suggest that the Local Government Board should, when schemes are suggested to them, consider the advisability of recommending the separate system, as they would thereby strengthen the hands of engineers in dealing with local boards. It must be remembered, however, that they had to do, to a great extent, with the water carriage at present in existence. Water-closets were already established to the number of many thousands, and they must be dealt with, and the principle on which they had to work was to get rid of the nuisance at the least possible cost. Therefore, while they had every respect for the A B C, and many other systems, he thought those who had to deal with the question practically must look first to the question of expense. Now, experience showed that lime was the simplest, best, and most efficient means of dealing with the question. He had tried the lime system at Ealing for many years, and it had proved thoroughly successful. This might be gathered from the fact that they were next door to the Conservators of the Thames, who had never attempted to interfere with them. He therefore suggested that this system should be tried by municipalities and other authorities before putting their constituents to the enormous expense required by many systems which were laid before the public. He firmly believed in irrigation, but also advocated the use of lime in conjunction with it, because in thus treating the sewage you got rid of that which was obnoxious, and obtained the compound which was most valuable to the agriculturist. You could then do with a minimum of land for turning the effluent

water upon, and the land so used occasioned no nuisance whatever, though it would produce most excellent crops. He thought if they waited until earth closets or any similar system were adopted throughout the country, they would have to wait a long time, and did not believe that any government would urge the adoption of any such scheme. As to the disposal of the sludge produced by the precipitation of sewage by means of lime, various methods had been suggested for disposing of it which he had not time to describe, but would only say it was to be dealt with, and without difficulty. He was now dealing with it at Ealing and in other towns in various ways, and in every town the treatment would depend upon the circumstances of the town and the nature of the soil, whether it were clay or light land.

Mr. A. M. Fowler (Salford) said it seemed to him that the arguments had been all on one side, for not one word had been said in favor of the manufacturers, though it would be a very serious question indeed for them if their interests were not carefully watched. In the case of the River Aire, at Leeds, there were very many large manufactories upon it above the town, and he remembered very well when the question was agitated there, the great mill owners got up a meeting at once, and formed themselves into a deputation to wait upon the Home Secretary. If any stringent or arbitrary measures were put in force to purify this river, no doubt the same course would be pursued, and opposition would be encountered. The question was not whether purification could be accomplished—for there were several methods of doing it—it was simply a question of expense, and therefore, if the A B C process could be worked so economically as had been stated, in a town like Leeds or Manchester, he thought it might be very usefully introduced in towns where they were so situated that land could not be obtained. He had had fish living in this effluent water several weeks by the side of a globe containing water supplied by the town, and strange to say the fish in this latter globe died two days before they did in the effluent water from the sewage. He had not the slightest interest in this process, either directly or indirectly. It so happened that in the neighborhood of Leeds and Manchester, there were two wealthy navigation companies, the Aire and Calder Navigation, and the Bridgewater Canal. The Aire and Calder Navigation Company were the custodians of the river throughout its whole water shed, and would not allow a manufactory or anything else to abstract one drop of water from the river without returning it again. Therefore if a manufacturer took a quantity of water, he could not turn it into the sewers, where it would pass down to the sewage works and be deodorized, but must turn it back into the river, so that the river by such an operation became fouler than before. As Sir Joseph Heron had said with regard to the Irwell, it was worse above the town than it was below it, because the manufacturers turned their refuse into the stream.

Mr. W. C. Sillar feared that the unanimity with which the meeting had received the first proposition as to the evils existing, and the necessity for a remedy, would not be found when they discussed the processes which ought to be adopted, nor did he think a room of that kind was the place where the owners of any particular process should advocate their ideas. The real judges of this matter were the town council, or sanitary authorities, in whose hands was vested the solution of this problem. In days gone by it was said that the problem was very difficult, because there was no known process by which you could get out of the difficulty. Now, on the other hand, they were told that so far from there being no process, there were so many that positively they could not make up their minds which to choose. He was much interested in one process, but at the same time, if a better one could be shown, he should be the last to lament it. His object was to see the rivers clear, and the wealth utilized which now was wasted. One of the great difficulties they had had to contend against was the apathy of town councils. A great deal was said about the expense of this process and of that, but they never calculated the expense of not doing it. It was as in the case of railway accidents, they never could get directors to avoid them until the damages given by juries brought them to reason;

and if a calculation were made of the sickness and death which arose from polluted water, the responsibility would be so heavy that public opinion would be brought to bear, and municipalities would be compelled to adopt some process or other to prevent pollution. A good deal had been said as to the advisability of separating refuse and fæcal matter from sewage, but as he viewed it the problem was given—sewage containing this matter, how was it to be treated? There were plenty of processes, and he trusted some legislation would soon be initiated by which the matter would no longer be allowed to rest in abeyance. Some of his friends had been willing to bear the whole expense, if towns would only allow their sewage to be treated so as to demonstrate the practicability of the process. This was not a question in which personal interest should be allowed to come into play; there ought to be some impartial tribunal appointed to say what ought to be done.

Mr. Alfred Smee, F. R. S., said he came to the meeting to learn and not to teach, but in consequence of some amount of misunderstanding which appeared to exist as to his views, and from what Mr. Hope had said, he felt bound to say a few words. He agreed with him that sewage must ultimately be cleansed in the earth, and that they never could get water which once had been sewage fit to again go into a stream without filtration through the ground. Many experimenters stated that they so purified the water that they could recommend it to be drunk, but there was no town in England where the inhabitants pumped back their sewage after they had purified it into their own water tanks. Only the other day, when at the Wallington Station, he asked what the state of the water was, when he was informed it was quite unfit to drink, that it had filtered through from the sewage irrigation ground. Although that was badly done, he believed that sewage might, after precipitation, be so cleansed by passing through or over the earth that it should be perfectly fit to again enter the river. But how was it done? It was put on the grass, where it destroyed the roots, and the engineers said that this grass was the best cleanser. Undoubtedly, because it was in precisely the same position as a scrubbing brush would be, every blade of grass being covered with water, and every blade wrapped round with fæcal matters, and this was given to the cows. The same thing continued when sewage grass was dried and made into hay, and if any one would take hay made from sewage grounds and rub it, he would find the nauseous, filthy matter encased upon it. As an impartial observer, and from experiments made at his own experimental gardens, he was able to say that sewage produce did prematurely decay, and he did not believe it was right to cut grass when covered with fæcal matter and give it to cows; common sense dictated that such grass was unfit food for cattle, though no doubt cows had a liking for foul food to such an extent that the man who valued his milk in India kept his cows carefully tied up, in order that they should not eat human ordure. With regard to the question whether sewage grass affected the milk, he had published experiments of his own to show that it did. A most elaborate set of experiments had been conducted at his farm yard, every day in the year, and they found it very difficult to make butter from sewage milk. Sometimes a change took place in the constituents of the milk, and the caseine would sometimes dialyze from milk produced in this way, showing that serious changes occurred in the animal economy, if cows were fed on excrementitious and not on pure grass. Some people might not care for the cows, but he, as a medical man, must care for human beings, and when he stated not only that grass was being used as a cleanser for sewage, but that water-cresses which were sent to London and consumed by the aristocracy, were used for this purpose, he thought it time to speak, and say that vegetable matters were not proper things to use as scrubbing brushes to remove the solid matter from sewage, though the earth itself might be employed with advantage.

The Rev. J. C. Clutterbuck said he wished to speak on the last branch of the subject, as to the evils arising from the non-separation of the rainfall from the sewage proper, these evils having come much under his own observation. This matter certainly appeared to him to assume most gigantic proportions, with

reference to London, which was situated on a tidal river, and owing to the flux and reflux of the tide this fæcal matter, as well as a great portion of the sewer water of the street, was stirred up by every tide, and oscillated backward and forward in the Thames in a way which few people would believe. He had also tried certain experiments with regard to the A B C process, the conclusion to which he came being that the difficulties of precipitation were so great that it would be almost impossible for it to be applied generally. He had had opportunities of seeing many places where sewage had been dealt with, and had come to the conclusion that it was only by its application to the surface, and filtration through the substance of the soil, that, as far as our present knowledge went, purification could be accomplished. He believed it had been so accomplished by Mr. Hope, and it was likely to be so by Mr. Bailey Denton, at Merthyr Tydvil, though he hoped that gentleman would not restrict too much the area to which he applied the sewage.

Mr. Edward Hall said there seemed to be some danger of forgetting that this sewage question was simply a branch of the grand question of the removal of all kinds of refuse, and it would be impossible to obtain the purification of sewage, whether removed by one process or another, unless street sweeping was attended to much better than it was in any town in this country. In Paris, during the time of the Empire, street sweeping was thoroughly attended to, and to that, and also to the peculiarity of the Parisian system as regarded house refuse, he attributed the comparatively low state of mortality there. He had made a careful comparison of the mortality of Paris and London, a matter by no means easy, because the census returns in France were made only once in five years, and he found that the mortality of Paris was very slightly above that of London, a proverbially healthy metropolis. The Paris system was to deposit the house refuse in the streets, and an admirable system of street cleansing being also adopted, he contended that it would be far better in London to follow the same system, and to remove it by an improved system of street cleansing, rather than to hoard it as was practically done in and about our houses, for by such a method not only would the rate of mortality be diminished, but the solution of the sewage question would be rendered much more easy. One great difficulty was to keep out of the sewers that mass of filth which was deposited in the streets, not ordinarily called house refuse. But if there were a proper system of street cleansing, a great deal of what now passed into the sewers would be removed by horse and cart.

Mr. Henry Morgan (Lodge Farm, Barking) said he was glad to hear Mr. Smee take exception to the evils which occurred on some sewage farms, though he was sorry he did not go on to say that he found none such on the large farm at Barking, where for eight years they had dealt with the North London sewage. They had there carried out experiments for the purpose of throwing down solid matter held in suspension by the Phosphate Sewage Company's process, and pouring the effluent water on to the farm, the result being that they grew such crops as attracted Mr. Smee's attention and approbation, and he might remind Mr Smee that they had had the pleasure of supplying him on two separate occasions with mangold-wurzel grown by sewage for the use of his own cows. Of course, if such practices as he had referred to were general, there would be an end of irrigation, but he hoped the meeting would remember that when they spoke of "purity" being obtained by passing sewage over dry land, or through it, or both, that the exact meaning of the word was rather debatable. He doubted very much whether the word "potable" was applicable even to the water which had passed through the land and been applied to growing crops; that was a point, however, which chemists alone could decide. With regard to the scheme which had been referred to by Mr. Hope, as laid before the Select Committee for the purpose of dealing with the North London sewage, as he represented the company which took that concession from Mr. Hope, he was bound to say that whatever the Select Committee might have thought of the scheme from the evidence then before it, he would undertake to bring evidence now which would show that it could not have been carried out successfully by private enterprise.

Mr. Bailey Denton wished to point out a little inconsistency in the remarks of Mr. Alfred Smee. He commenced by speaking of the great advantage of filtering sewage through soil, and in fact admitted that the difficulty could be overcome by that process, and then he spoke of the roots being so covered with sewage matter that they were repulsive in character. What Mr. Smee stated was an utter impossibility, because, if the sewage passed through the soil as well as over the surface, it was perfectly impossible that the sewage matter could cling to the roots of the grass.

The Chairman thought the meeting would agree with him, that the Council of the Society of Arts were perfectly justified in calling together this Conference, since they had heard persons from all parts of Great Britain, though they had not heard any gentleman from Ireland who could speak as to the state of the river Liffey. Possibly the case of Ireland did not present the same urgency as other parts of Great Britain, because there were not so many manufactories there. He was glad to notice that several suggestions had been made; one, no doubt, from a very good motive, from General Scott, to the effect that if they legislated too rapidly, they might injure their cause, and that they should first ask the Government to insist on the solid matter being taken out of sewage and the liquid only allowed to run into the streams. He did not think his friend General Scott had had so much experience of Lancashire and Yorkshire streams as Sir Joseph Heron and himself had long had, because if some of the coloring matters now turned into these streams were allowed to remain, their condition would be perfectly insufferable. They had all seen or heard of Gainsborough's "Blue Boy," but if they went to some of those streams in which indigo and Prussian blue was running down, they might see fifty blue boys come out; and if they went to a stream in the neighborhood of which black dye was used they might see fifty boys go in, and fifty "men and brothers" come out in a state far worse than that in which they went into the stream for the purposes of ablution. It was therefore quite as necessary to get rid of the soluble matters as of the solids, especially in fishing streams, for one of the most poisonous substances, and one of the most common which destroyed trout and salmon more than any other, was oil of vitriol. This could be removed as easily as possible by simply filtering it through lime-stone, and why should that be allowed to go into a stream simply because it was soluble? No doubt it would much improve the system of sewage if all soluble matters were taken out, but that was not sufficient. The meeting seemed to agree that the rivers were intended for the use of the whole community who inhabited the drainage area through which the rivers flowed, for the various purposes for which rivers were useful to mankind, and that no one town in that area had a right to appropriate that river and destroy its usefulness to other communities; similarly, that no one manufacturer had a right to say, I add to the production of the country, and therefore I will take the river, which is intended for the benefit of the whole district, and destroy its usefulness before it comes down to others. Each river therefore ought to be preserved in such a state of purity—absolute purity they could not obtain—that it might be of use and benefit to the whole drainage area which it watered. What then was the stage at which they had arrived? They would remember *Punch's* cartoon of last week, referring to a picture of Millais, where Mr. Disraeli said, with reference to the Arctic expedition, "It is possible; therefore it shall be done." By the first resolution it had been asserted that the purification of rivers was possible, and therefore it should be done. It was not for them, out of so many competing schemes, many of which were excellent, to select one and say it should be applied, but as a chemist he might be allowed to say that he had looked at all the different kinds of impurities which passed into the rivers, he had seen the different methods which had been used for removing them, and there was no one class of impurities which could not be removed, generally with great profit to the manufacturer. They must not attempt to do this in an arbitrary way, but must allow manufacturers to understand that the country intended to have its rivers pure. They would not say to any man, you shall do this or that, without full time for consideration to apply the

remedies, but that it was the intention of the public and of the legislature to purify the foul rivers of the country, and, as Mr. Thom had showed, he believed the manufacturers would then come to the legislature and ask for further restrictions. This had been their experience with the alkali works. A few years ago they used to foul the air most abominably with muriatic acid gas, and cried out very much against being forbidden to do so, but they had now found that they could not only prevent this easily, but that they could do so with profit, and they actually came to Parliament and said—"Be more severe." So he believed it would be with manufacturers generally with regard to the fouling of streams; it would be for their benefit as well as for that of the community at large. He believed, therefore, the practical result of the Conference would be that they ought to tell Mr. Disraeli that the thing was possible and that it should be done. If that were done, he believed a solution of the question was not very far from accomplishment, and that they would soon see their beautiful rivers restored to that bright and clear color which they ought to be, instead of being, as they now were, a disgrace to the country through which they passed.

SUEZ CANAL TONNAGE.

From the "Nautical Magazine."

In making any dock, or harbor, or canal, or any approach to it from the sea, the undertakers of the work have to provide for the maximum size of ships likely to use it.

The three points they have to consider are: (1) of what width are the ships for which they have to provide; for unless the dock-gates, and the channels, and the canal are wide enough, it will be of no use when completed. But width is not the only question. They have also to consider and provide for (2) *the length* of ships. A short, wide ship will be able to navigate in a channel, or in a dock, which would be wholly inaccessible by long, narrow ships; and thus it happens, that in order to provide for long ships, locks must be of great length, basins must be of great area, and the bends and turnings in channels and canals must be carefully and expensively made, so as to avoid anything like sharp curves; but, still further, length and breadth are not the only elements, for there is a third element—viz. (3), depth of ships. It will be useless to provide a broad and well-arranged channel without regard to its depth, or to construct broad and long locks, or docks, or canals, without regard to their depth, for large ships must be deep ships. Therefore, sufficient depth has to be provided; and to provide depth is one of the most expensive parts of the construction or arrangement of the undertaking.

A dock or canal company having been at the expense of providing adequate length, breadth, and depth, for the accommodation of ships, must necessarily be most equitably remunerated for their outlay, by levying dues on ships on a system founded on their length, breadth, and depth. It is absurd for the shipowner to say to a dock or canal owner, "It is true I occupy so much space in your undertaking; it is true my ship requires so much length, and so much breadth, and so much depth, and you have provided them, but although I occupy that space, and could not get through unless you provide it, still as half my ship is for my own purposes occupied one way, and the other half occupied the other way, I ought only to pay as if my ship were half her actual size." But this is exactly in effect what is urged. On the other hand, we must notice that dock owners are very unfair to steamship owners, when they charge as much for a steamship occupying space for a day or two as they do for sailing ships occupying space for several weeks.

The gross tonnage alone, being founded as it is on the actual cubature of the internal contents of a ship, is the only tonnage that takes into account the three elements of length, breadth, and depth,

and for such an undertaking as the Suez Canal, where time is no element in the charge, or for an international ton, it is the best, because it is the only accurate gauge of the description of the ship.

And even for charging light dues, the gross tonnage is the correct standard, for the following reason: The payment is made for services rendered. In the case of the steamship *Asia*, formerly of the Cunard Line, when she had on board machinery worth say £50,000, she paid on the register tonnage of say 1,200 tons. She grew old, the engines were taken out, and she was converted into a sailing ship, and was, as a fact, about half her former value, and had to pay dues on the whole tonnage of the hull, or 2,000 tons, or thereabouts. Register tonnage has been adhered to by steamship owners, because dock owners do not allow time as an element of charging dues, and the steamship owner looks upon the advantage he gets by paying dues on the register tonnage as a sort of rough and ready compensation for his frequent visits; but admits universally that if time were taken into account, gross tonnage is the proper tonnage on which to levy dues. And again, as between ship and ship, the gross tonnage is the proper system, because (1) it is the only system founded on the cubature of the hull, and (2) because it is free from any of those disturbing causes arising from deductions for engine-room, and (3) because it leaves the ship owner free to arrange the internal part of his ship as he pleases, instead of having to arrange it (in a way that is fair to nobody) for the purpose of getting a small register tonnage.

The above are some of the reasons in favor of gross tonnage as the basis of taxation for the Suez Canal and of an international ton.

Our present net register ton is unjust in the extreme in the case of steamships, both as between steamship and steamship, and as between sailing ship and steamship; and, further, it is monstrously unjust to the shareholders of the canal, and as between nation and nation. No one knows this better than M. de Lesseps. This subject is exhaustively discussed in our number for February, 1871. We, therefore, refer our readers to that article, merely mentioning that it was deemed to be of sufficient importance and accuracy to be reprinted by the Board of Trade.

The system in use in the Danube is a fairly good system for that river; but we must recollect that it was only adopted failing the adoption of the gross ton. And we must further bear in mind that, although we have only few positive arrangements internationally as regards the register ton, the gross ton is as a fact almost already an international ton; for the gross tonnage, according to our system, is stated on the papers of ships of the following countries: Austro-Hungary, France, Italy, Denmark, Germany, United States; and it is from the gross tonnage so stated, that in many cases, and by various ways, the register ton, or chargeable ton, is arrived at after deduction in foreign ports.

Other systems have been proposed: (1.) A fixed deduction; but a fixed percentage, made applicable to all ships, whatever their trade, would be unjust, as it would operate unequally between ship and ship, and because, to meet extreme cases, it would have to be very large. To take an actual case, it would be absurd to say that, because the *Republic*, in making a voyage to the coast of South America, would require say 40 per cent. deduction, another ship, or the same ship, going to New York or to Oporto, should have the same deduction. She would, in fact, in the latter case, have a deduction for space in which it would be well known that she ought to carry cargo. In one case there would not be deduction enough, and, in the other, cargo would be carried in the deducted space; or, if not, what is worse, it must remain idle, or be filled with a dead weight of coals that are not wanted. How these arguments apply at all against gross tonnage, pure and simple, it is difficult to see.

Another proposal we have seen is that, having fixed the gross tonnage, there should be deduced therefrom a register tonnage that shall be less than the gross tonnage, according to the nature of the service of the ship; that is to say, a long-voyage ship should have 30 per cent. deducted; a short, foreign-going voyage ship, 20 per cent., and a coaster 10 per cent.

This would have involved the following awkwardnesses:

(1.) An addition of about 20 per cent. to the dues paid by all home trade coasting steamships. In some cases, 40 per cent.

(2.) An addition of about 13 per cent., in some cases more, to the dues paid by short-voyage foreign-going steamships.

(3.) An addition of 3 or 4 per cent. to the dues paid by all other steamships.

(4.) The alteration of the official register tonnage where a steamship is laid on for fresh voyages.

Seeing then that by such a system whatever tonnage is to be adopted is to be deduced, and is to be a fixed proportion of the gross tonnage for each class of ship, it will be much better to adopt the tonnage (gross) at once, and then, if necessary, to make a reduction of 10, 20, 30, or 40 per cent. in the rate of dues. Ship owners have, however, in the case of the Suez Canal a right to demand that the charge shall be made on the nett register tonnage, for Mons. de Lesseps pledged his word that it should be so charged, and, on the faith of his word, they have specially constructed ships for the Canal.

It was argued against gross tonnage for the Suez Canal, that it would be unjust between three classes of ships: A, high-power, passenger; B, cargo, full power; C, auxiliary; but by charging on the register ton we should be practically shutting out auxiliary screws, and favoring the high-class freight-earning mail steamer; whereas a charge on gross tonnage, which leaves the owner free to use his space as he likes, is a charge on the whole venture, and not on the least valuable part of it.

One very important fact is, that by charging on the gross tonnage every owner is at liberty to vary the internal arrangements of the ship as trade requires, while by charging on the present register tonnage, the full-powered monopolist's steamer obtains an immense advantage, and is able to carry passengers, which, as freight, are, in some cases, the best paying of all cargoes.

As a ton for the Suez Canal, we think we must say, failing the gross tonnage, the Danube rules for nett tonnage now proposed are the best rules. They are, at any rate, better than a fixed proportion of the gross tonnage for many reasons, but especially for the reason that they will lead to the construction of large and light cool engine-rooms, and save the country a good deal of expense in connection with sending home invalided engineers and stokers. A fixed percentage once allowed for machinery would lead to the direct contrary, and would be very damaging to the personnel of the Mercantile Marine; and they are better than a sliding scale of percentages, which is satisfactory to no one but the ship owner who, by a juggle in constructing his ship, is able to shift the charges on to some one else.

THE Paris Academy lately received, from a dyer at Puteaux, a note, which was listened to with manifest incredulity. It referred to a fire produced, the note said, by the electricity liberated when certain stuffs are rubbed in a bath of benzine for removal of greasy matter. On further inquiry, however, the phenomenon was ascertained to be real. The case was thus: A workman was charged to take the grease out of a piece of cashmere by washing in a benzine bath; he at once plunged 6 metres of the stuff into the bath, rubbed it vigorously, then hung it to dry, on a peg above the bath. Now, he had often remarked before (and called the attention of others to it), that when the cloth was brought out of the bath and doubled on itself, a strong crackling took place, accompanied with light and sensible pricklings in the hands and the body. In the present case the bath was suddenly inflamed, and the workman was burnt on his arms and hands. This inflammation was naturally attributed to the electricity. This new phenomenon is of some interest, considering the frequent employment of such processes as the one in question; and it may be hoped that the committee which was appointed will throw some light on it.—*English Mechanic.*

THE Geographical Society of Paris recently appointed a Commission to draw up instructions to masters of vessels as to the study of the physical geography of the sea. These are now published, and are sent gratuitously to all who care to take up the subject.

THE PRINCIPLES OF DRAWING, GEOMETRY, AND COLOR, AS TAUGHT AMONG THE HINDOOS.*

From "The Builder."

GEOMETRY has been cultivated for many centuries in India, both among Hindoos and Mahommedans as a branch of science as well as a necessary element of education. The theory as well as the practice has been thoroughly understood by the educated natives, and the principles upon which it has been taught, not so much in schools as in the domestic circle, prove that geometry has had an importance assigned to it in former times by enlightened minds who foresaw that it might be made the means of improving the taste and diverting it to the study of simple and beautiful forms. The mode of teaching geometry to children is very simple and impressive, and the materials employed are of the cheapest. A Hindoo child is first taught to draw with the points of the fingers on the floor covered with sand to the thickness of half an inch. The surface of the sand is made level with a straight piece of wood or a piece of split bamboo. Dots or depressions are first made in the sand with the points of the fingers held at certain distances, the thumb, fore, and little fingers being generally employed as the compasses. At first the eye is accustomed to judge of distances by the position of dots—the next step is to connect these dots by straight lines—then to draw straight lines regularly between the dot—then to prolong these lines till they meet beyond the dots. Square forms are usually selected as being the easiest for a child to draw, and more attention is bestowed on educating and accustoming the eye to judge of distances than in drawing perfectly straight lines. At first plain squares are drawn preserving the dots; then various combinations of the square, vertically, horizontally or diagonally arranged. This is, perhaps, the most impressive way of teaching the various uses and combinations of the square, and of educating the eye to judge of its relative size and value for filling given spaces, as it can be seen at a glance, and without much effort on the part of the child, which squares are large and which small. The multiplicity and variety of these patterns in which the square forms the basis are very instructive. This system of instruction has the advantage of explaining itself, without being perplexing or intricate, and of accustoming the child to draw lines in a bold, free way from the shoulder and not from the wrist, as in our systems of drawing. The patterns are usually drawn at first from 18 in. to 2 ft. in length, so that each square would vary from 2 in. to 4 in. After a facility of drawing them with single lines has been acquired, they are done on a larger scale with double lines with the fore and little fingers. Curved lines are then added to complete the border of the pattern. The square is looked upon by the Hindoos as the most important geometrical form, and the basis upon which the measurements of their designs and patterns are to be laid down. These illustrations may have a special interest, as they were drawn by the Hindoos themselves, and many of them had been in use in families from whom they were purchased as the ordinary patterns in daily use in Hindoo families. They hardly deserve the name of drawing lessons, as there is both a religious and a caste importance attached to them, for the different trades and occupations of the Hindoos are indicated by the patterns which are drawn in white on the road in front of the houses. In some families there are as many as 1,200 patterns in use, and it is occasionally the boast of the women who draw them, that they can go on for three years giving a new pattern every day. The name given to this kind of pattern in Southern India is Mogoo, and when girls are about to be married, one of the tests of her domestic education is the number of these patterns which she can draw. There is some sense in this, for it is an index of the care that has been bestowed on her domestic education, and a proof to her neighbors that she has been taught to clean the house, and to say her morning prayers to her preserving or her

* A paper read before the Edinburgh Architectural Association by Alexander Hunter, M. D.

destroying deity. Among the Buddhists and the early Hindoos the square was supposed to be typical of the solidity of the earth; the triangle, of fire; the circle, of the sea or water; and the crescent, of air. To these the later Buddhists added a fifth element, or the winds, represented in some instances by a pyramid with turn-up points, as seen in many of the pagodas of Burmah and China, and in a few of India. But to return to the square and its uses as applicable to ornamental purposes. The Hindoo child is taught to examine and to reproduce for itself, and to attach some meaning to each; for instance, in several of these patterns we see a central square, with numerous others arranged about it in pleasing combinations, each square touching the next, but the idea of solidity or continuity destroyed, and an approach to decoration given, by the mere arrangement of a few straight lines within squares. You will have no difficulty in detecting that the ideas for some of these patterns have been suggested by bamboo mats, others by grass mats, and a few by cloth weaving. After a facility of drawing in sand square forms and patterns of simple combinations of straight lines has been acquired, the child is taught to draw them on the cleanly-washed mud floor or on the stone steps at the door; but the style of drawing differs materially from the methods followed in Europe. A little chalk or chunam in fine powder is held in half a cocoanut-shell, and the points of the fingers are dipped into it. A succession of dots is laid down to mark the leading parts of the pattern, the lines of which are drawn by sprinkling the powdered chalk, and not by drawing with a point as we do. In this way a steady hand and a bold freedom of style are acquired, which are frequently carried to great perfection in after life by both Hindoo men and women when designing patterns for weaving. In order to make the patterns more attractive to children, various simple but cheap and tasteful modes of combining colors with the drawing and geometry are had recourse to. One of the most common methods is to fill up the squares or spaces with colored powders, and either to trim up the lines of junction with a split and pointed bamboo, or to pull some flowers to pieces, and to arrange the petals along the sides of the squares, so as to hide the inequalities; for this purpose the flowers of the white jessamine are most frequently selected; sometimes the yellow jessamine is used. The colored powders used for filling up the spaces are natural ochres for the reds, yellows, browns, and purples, mixed with chunam to give brightness. When the following colors are used—tumeric, king's yellow, orange and yellow, chromates of lead, or red lead—the materials with which they are mixed are arrowroot or starch. When delicate blues or lakes are employed, the material with which they are mixed is kaolin or porcelain earth. The object of using these different substances with particular colors is to avoid the chemical action of the lime on some of the colors when applied to a wet floor. This shows a considerable knowledge of chemistry. It will also be remarked that the colors are at first used in their purity, and the chalk, kaolin, or starch is added to brighten the effect. In this simple but ingenious way great numbers of patterns are produced. The use of secondary colors, as green, purple, and orange, is taught by simply washing the floor after it has been colored with the three primaries—red, blue, and yellow. The effects of the tertiary color—russet, in which the red predominates; olive, in which the blue; and citron, in which the yellow is in excess of the other two—are often very beautiful when these are interspersed with other colors. On looking over a number of patterns, it will be remarked that blue is used very sparingly, and always of a very tender shade, and that its place is often supplied by a grey; that white and black are chiefly employed in thin lines or partitions between colors, and seldom as principal masses. It may not be out of place to remark that the effects produced by these colors, flowers and green leaves on the mud floor are far brighter than can be produced in an illustration. It is customary to wet the floor with rice water before sprinkling the colors. As yet the natives of India have seen very little of the fine arts beyond a few busts, and statues, and bronzes of our Indian celebrities, and these not always by our best artists. The works of Chantrey, Foley, and Weeks have riveted their attention; but

there are others of our townsmen, as Brodie, Lawson, Clark Stanton, Webster, and the two Stephensons, who are rising, or have already risen, to eminence. Let us try to put some of the best works of these and such like artists before the Hindoos, and if we assist their own modellers and sculptors to produce similar works of their own countrymen, we shall be doing a service to India by helping them to throw aside some of their prejudices of caste, and their more degrading sculptural obscenities. Art in India was far grander and purer 2,000 years ago, or during the early Buddhist period, and there are sculptures still in fine preservation, from having been carved in granite, that show proofs of a careful study of chaste and simple nature. In order to make art telling in India, we must teach them to make it profitable, and if possible cheap, for there are but few patrons of real art in India.

THE PASSIVITY OF IRON.

From "Iron."

To produce in a certain manner the somewhat capricious phenomena of passivity, says M. de Regnon, I use iron wires or rods of fencing-foil, the surface of which is protected, for a certain length, by a glass tube or a layer of mastic. The free extremity, with a length of 2 to 3 centimetres, is plunged entirely in the acid.

I. An electric current *entering* by the iron into nitric acid, renders the iron passive while the current lasts; and after rupture of the current the iron remains passive. A current *leaving* by the iron destroys the passivity, and this change of state may be reproduced indefinitely. Iron acting as positive electrode in a mixture of sulphuric acid and water, liberates oxygen, is weakly attacked, and becomes passive for nitric acid. A reversal of the current's direction destroys the passivity.

II. One may *stop* the attack of iron by nitric acid, by touching or (better) rubbing it in the nitric acid with a body that is a good conductor and not attacked by the acid, such as platinum or conducting charcoal. This action of charcoal explains why steel and cast iron become passive of themselves. The experiment succeeds better the larger the surface of contact, and the larger the total surface of the body which is not attacked. Further, the more concentrated the acid, the more easily is the passivity obtained.

III. The contact of a metal attacked by acid destroys, it is known, the passivity. If, then, we put in contact a passive iron wire and an active wire, the final effect will be either the attack or the passivity of both wires. We may unite in a single experiment these two contrary results; immerse the extremity of a piece of foil (the whole surface of which is exposed) in nitric acid to a length of 2 or 3 centimetres. After a short attack, the part immersed becomes passive, and is covered with a dark deposit containing carbon. This done, if we suddenly immerse the foil to a fresh length of 3 or 4 centimetres, the attack commences from above, is propagated to the lower part, and, when the passivity is anew produced, we find the whole of the immersed length charged with black deposit. In this first case the active portion destroys the passivity of the extremity. If, on the other hand, we immerse the foil slowly in the acid, it will remain passive without the part newly immersed undergoing the least attack, as is evident from its clear and bright look. Here the passive extremity communicates its state to the other portion.

IV. We may bathe the end of a wire in water, without destroying the passivity, provided care is taken not to immerse the wire in the water beyond the protective mastic. We may even scrape the wire, in the water, with another passive wire, or with the end of a clean tube of glass, without its state being changed, and this experiment quite destroys the explanation of passivity by formation of an insoluble deposit.

V. I have tried the action of other liquids after having each time bathed the passive iron in pure water, and I have

verified the proposition (already known): Oxidating substances are without action on passive iron. Deoxidating substances destroy the passivity.

VI. We may perceive that the actions of contact are reducible to electric actions by means of the following experiments:

1. Connect together a wire of iron and a wire of platinum terminating in a spiral. Plunge the free end of the iron in the acid, and when the attack has commenced, introduce the spiral of platinum into the same glass, or into another glass containing acid, and put in communication with the first by a bridge of platinum. In an instant the iron becomes passive. The same experiment succeeds on connecting iron with conducting charcoal instead of platinum.

2. On the other hand, connect an iron and a copper wire. Plunge in the acid the free end of the iron, and render it passive by rubbing with platinum or with passive steel. This done, introduce the end of the copper wire into the same glass, or into another glass as above, and immediately the iron is attacked.

3. Plunge into a glass filled with acid, or into two glasses connected by a bridge of platinum, the two extremities of two wires of iron connected exteriorly by a conductor. If we then rub in the liquid one wire only with platinum, both become passive; if we touch one wire with copper, both become active. These experiments are more delicate than the preceding, owing to the electric resistance of the liquid.

VII. The passivity may be destroyed in another manner, which shows the *role* of electricity. Connect the wire of a galvanometer, on one hand, with a spiral of platinum or copper which has been plunged in a conducting liquid that does not destroy the passivity—*e. g.*, a solution of nitrate of potash—and, on the other hand, with a wire of iron protected by mastic as explained. Then close the circuit by introducing the iron into the nitrate; the needle indicates an immediate and permanent current going from the galvanometer to the iron. We obtain the same result (which is easy to foresee), if, after rendering the iron passive, and washing it well with water, we immerse it an instant in a liquid which destroys the passivity; *e. g.*, in a solution of marine salt. But if we close the circuit after having washed the passive iron in water, or in a liquid *without* action on the passivity, we perceive a slight movement of recoil in the needle, indicating a first current of very short duration, going from the iron to the platinum by the galvanometer; then the needle is forced in the contrary direction, and indicates a permanent current from the platinum to the iron. But one finds that, immediately this action is produced, the iron is become active again.

VIII. All these experiments seem to me to legitimize the following conclusions: 1. Most of the causes which produce passivity in iron may be reduced to a voltaic force carrying the oxygen to the iron and polarizing it on the surface of this metal. 2. Most of the causes which destroy the passivity of iron may be reduced, either to a voltaic force of the contrary direction, or to a current due to polarization of the oxygen, and by which it is exhausted; or, lastly, to an absorption of the polarized gas by a body that has avidity for oxygen. I hope shortly to show that these phenomena of passivity are more general than is supposed.

IX. We can now explain two experimental precautions that were insisted on: 1. It is necessary to protect, with an impermeable layer, the portion of wire which is not plunged in the acid, otherwise the acid vapors bring this portion into a state which is opposed to the passivity of the immersed part. 2. When we bathe the passive extremity in water, the metal should not be immersed above the mastic, otherwise the passivity is immediately destroyed, for a circuit is closed by which the polarization is exhausted.

Most of the above experiments were made with nitric acid, marking 35 deg. B.

It appears as the result of some experiments made in Berlin, that while a bar of ordinary bronze was utterly incapable of bearing a strain amounting to 10 tons per square inch, a bar of phosphor-bronze bore this strain applied as tensile 408,230 times before giving way. A second bar of the same phosphor-bronze actually withstood 147,880 applications of a load of 12½ tons to the square inch without fracture.

TECHNICAL EDUCATION.

IN WHAT WAY AND AT WHAT STAGE CAN TECHNICAL INSTRUCTION BE BEST INTRODUCED INTO OUR SYSTEM OF NATIONAL EDUCATION?*

From "Nature."

It will simplify the consideration of the subject the discussion of which I have been requested to introduce, if we admit frankly that in England at any rate (I am glad to believe that Scotland is more fortunate) we do not possess a system of national education. Such a system, as I conceive it, should afford to all the children of the nation adequate elementary instruction, and, moreover, should offer to all, so far as their capacities and other circumstances will enable them to take advantage of it, full opportunity for further mental cultivation. There are lying before me the calendars of two German schools for boys of the middle class intended for a mercantile or industrial career; the Friedrich-Werder Gewerbe, or Trade School of Berlin, and the Real Schule, under the direction of Dr. Schellen, at Cologne. The courses of each of these institutions following after some preparatory teaching in an elementary school or at home, where reading and writing together with a little arithmetic have been acquired, retain their pupils during nine or ten years; and boys who, according to the reports, were to become mechanical engineers, builders, postmasters, merchants, and chemists, left those schools last July, having attained the ages of seventeen to twenty years. The Real Schule of Cologne, the average number of whose pupils is 580, has 28 masters; the Gewerbe Schule of Berlin, averaging 540, has a staff of 32 masters. In every German town of the least importance there are, in addition to the Gymnasium or Classical School, one or more technical schools resembling those of Berlin and Cologne; the numerous Universities and Polytechnic Institutions furnish the requisite staff of teachers. The fees are small. I have no information as to those of the schools I have quoted, but I find from the prospectus of another very celebrated trade school, that of Barmen in Westphalia, that its school fees for the year are from 3*l.* in the lowest to 6*l.* in the highest class, and that boys whose friends do not reside in the town are boarded for 25*l.* The governments, the municipalities, and private persons vie with each other in placing at the disposal of poor scholars of the elementary schools who have shown superior capacity, the means of continuing their studies in these secondary schools.

I need not describe the elementary schools of Germany and Switzerland; it is now well known that, in them, the children of the poor receive, up to the age of fourteen years, sound elementary instruction, not confined to reading, writing, and arithmetic, but including geography, the outlines of the history of their own and other European countries, a modern language, some elementary teaching in science, and instruction in the religion which their parents acknowledge.

As contrasted with a system of education such as I have referred to and excluding the great public schools, available only to the rich, we have in England for the middle classes schools like those attached to King's and University Colleges, the City of London School, the Bristol Trades School, and, thanks to the Endowed Schools Commissioners, a few efficient or at any rate progressive grammar and endowed schools, among which I would more particularly name the school at Giggleswick, near Skipton, as one where instruction in science has been included in the general plan of instruction, and a small number of exceptional private schools in which a praiseworthy attempt is made to adapt the instruction to the requirements of industrial and commercial classes. These schools, however, rarely retain their pupils beyond the age of fifteen to seventeen years, and when all are reckoned they are utterly inadequate to the wants of the population.

Of elementary school buildings we shall soon have a sufficient number, and it is probable that the duty of the parent to send his child to school will, in some way or other, be in all cases made a legal obligation; but so long as the necessity

*A paper read before the Social Science Association, by Mr. B. Samuelson, M.P.

of rendering our training schools for elementary teachers thoroughly national and efficient is not acknowledged, and so long as the instruction of the children in elementary schools is left in a great measure to the care of other ill-taught children, called pupil-teachers, of from thirteen to seventeen years of age, we cannot hope that our poor will receive proper elementary instruction.

Until the English approach the German schools in number and value it would be vain to expect that technical instruction will be universally accessible, and we can only hope for its gradual introduction, availing ourselves of existing resources, with such improvements as may be looked for under the stimulus of the increasing interest evinced by some of our great corporations, by the parents themselves, and consequently by the Legislature.

One important step in the right direction has lately been taken. Although the political chief is still a species of odd man whose duties include the passing of Ballot Acts, the suppression of foot-and-mouth disease, and the negotiation of Washington Treaties, the Government departments of literary instruction and of Science and Art have been placed under the control of a single permanent administrative head.

I understand technical instruction to include, besides the teaching of industrial manipulation, which for our present purpose we may exclude, firstly, drawing, mathematics, and the physical sciences, which are the bases of the industrial arts; and secondly, the application of those sciences and of the art of design to industrial purposes. I should place in the first division such subjects as:

Pure Mathematics, Chemistry, Physical Geography, Geometry, Physics, Biology, Theoretical Mechanics, Geology, Astronomy, etc.;

and in the second—

Building Construction, Naval Architecture, Applied Mechanics, Machine Construction, Chemical and Manufacturing Technology, Metallurgy, Agriculture, etc.

Although this list is incomplete, it will be obvious that the field is too wide to be covered within the school period, even when the pupils remain at school to the age of adolescence; bearing in mind always that instruction in technical subjects to the exclusion of other branches of a liberal education would defeat its own object. Much more is this the case with children leaving school between the ages of thirteen and sixteen. The choice of subjects must vary with the age at which school instruction is to terminate, and with the future career of the scholar.

A condition precedent, however, to the possibility of technical instruction is a due provision of science teachers. For these we must look, in the main, as to elementary schools, to our training colleges, assisted by such institutions as the Science School of South Kensington, and as to secondary schools, to the Universities, and to institutions like King's College, University College, and Owens College. The training colleges should add a third year to their curriculum; instruction in mathematics and in some of the other subjects which I have included in the first division should be part of the obligatory course; and no elementary school containing, for example, 100 children and upwards should, after a certain date, receive the Parliamentary grant on results, unless it had a teacher who had passed satisfactorily in geometry, in physical geography, and in physics, or in biology. A man thus qualified, having become familiar with the method of science, could, if he chose, afterwards acquire other theoretical subjects as well as those of application, included in the second division—for instance, machine construction, chemical technology, or agriculture—availing himself for that purpose, as to the first class of subjects, of the annual courses for elementary teachers at South Kensington, or of any other means of instruction which may be within his reach. But if he stopped short at the limited but exact instruction in theoretical science which I suppose him to have obtained in the training college, he would be infinitely better qualified as a teacher than if during that course he had taken up a greater range of subjects superficially. Whether he be competent to teach many subjects or not, the children of the elementary schools whom he is to instruct have not time to acquire more than the rudiments of one or two theoretical sciences. At the same time an elementary teacher, who is qualified to give instruction in the applied sciences, will find employment in adult classes, such as those in connection with the Science and Art Department.

Assuming, then, that every elementary school for one hundred pupils and upwards, which would include the principal village schools, had a master or assistant qualified in science, the course of such a school should include, for all the children, linear drawing and lessons on common objects which would be illustrated by locally accessible specimens; the ordinary reading-book should also describe in familiar language the phenomena of nature. Those who are acquainted with the admirable text-books on Elementary Science of Prof. Balfour Stewart, Dr. Roscoe, and others, cannot doubt that the task of compiling such a reading-book will be undertaken by competent hands, as soon as the want of it becomes felt. Indeed, I am not sure that it does not already exist among the publications of the Irish National Board. The older children, those between the ages of ten and thirteen, should receive instruction in physical geography, in the elements of trigonometry, and, from the age of eleven or twelve, in the rudiments of biology or of physics, perhaps, in some exceptional cases, of both. More cannot be done for them in the elementary school; a few should be drafted into the secondary school; but the greater number would at the age of thirteen become full time-workers in the field, at the bench, or in the factory; possessing however, as is now but rarely the case, the elementary instruction required for taking advantage in their leisure hours of the science classes which are to be found in almost every district of the United Kingdom. How much may be done there is evident from the success of the Andersonian University in your city, with its 1,400 students, to whose founder belongs the honor of having been, more than a century ago, the originator of scientific instruction to the working classes. Children thus taught from the commencement by such masters, when they afterwards receive instruction in science, would not be subjected to, and would revolt against, cram like that recorded in the Report of the Science and Art Department for the present year, in which Prof. Ramsay, the examiner in geology, says that "candidates answer one of last year's questions in place of one of this year's, as if they had been specially crammed in last year's examination;" and Prof. Carey Foster, acting with Dr. Tyndall as examiner in acoustics, light and heat, states that a good number of candidates in the advanced stage "suppose that in order to *damp* the vibrations of a string it is needful to *wet* the string," and "that a ship is the kind of vessel that would usually be employed for containing air."

Among other conspicuous examples of adult instruction in science given to the class whose education has been received in elementary schools I may name the lectures for working men of Owens College, numbering more than 600 students, under the gratuitous tuition of the professors of that institution, and those of the Miners' Association of Cornwall and Devon, organized some dozen years ago by Mr. Robert Hunt, F.R.S., Keeper of Mining Records, whose teachers seek out the working miner in his village and make him familiar with the laws of the forces and the properties of the matter with which he is brought into contact in his daily work. But time is wanting to allude further to the subject of adult elementary instruction in science, nor will I enter into the question of science teaching in our great public schools, which has been inquired into by Mr. Norman Lockyer, F. R. S., the secretary of the Royal Commission on Scientific Instruction, whose report will doubtless be forthcoming before long. In secondary schools, assuming the existence of competent teachers, and that they retain their scholars from the age of eight or nine to sixteen or seventeen, I should commence, as in the elementary school, with lessons in drawing and on familiar objects, and in physical geography; and introduce mathematics, beginning with geometry at the age of eleven or twelve, continuing it until the pupil leaves school; systematic instruction in the elements of natural science might begin at the age of ten to eleven with natural history, including geology; and the six years until the pupil leaves at the age of sixteen or seventeen could be made readily to include successively the elements of that science and of physics and chemistry. With the exception perhaps of applied mechanics, it would not in my opinion be possible to include the applied sciences, but the teacher would illustrate his instruction by practical ap-

plications. Work in the laboratory is a necessity if a thorough appreciation in kind, however limited in extent, of natural science is to be acquired; but the experience of the Rev. W. Tuckwell, of the College School at Taunton, communicated to the British Association, and of others, shows that a school laboratory need not cost more than 200*l.* to 400*l.*

Only in those cases where school education is continued to the age of eighteen or nineteen years would it be desirable to introduce such subjects as building, or machine construction, or chemical technology. In all other cases more real progress would be made by devoting all the available time to theoretical science. The scholar who enters into active life as an apprentice at the age of sixteen or seventeen, would see in the workshop the application of the principles which he would have learnt at school, and, if diligent, he would find opportunities of further study in adult classes, in factories, and in text-books on special subjects. For instruction in the entire range of theoretical and applied science it would be necessary that the student should continue the course, commenced during the school age, at the University or at a Polytechnic Institution such as there is now some hope that the Science School at South Kensington may become.

Although I have excluded instruction in technical manipulation from the subject of this paper, I think it right to add that the students of King's College and of King's College School save much time and drudgery during their pupilage by the practical skill acquired in the workshops attached to the College, and that according to competent observers like Mr. Nussey, of Leeds, the artisans of Elberfeldt, Crefeld, and other continental towns derive great advantage from the schools of design and so-called weaving schools.

I should not fulfil my duty if I were to conclude this paper without acknowledging, though no alarmist in regard to foreign competition, that other nations, less energetic, less rich in accumulated capital and practical experience, and without the advantage of our great mineral resources, are, thanks in a great measure to their superior technical training, making relatively greater advances than ourselves in many branches of industry, and that the conviction of the necessity for such training has not arisen among ourselves a day too soon. Happily it has arisen, and in the most desirable quarters. Manchester, by the judicious enlargement of Owens College, to which its merchants and manufacturers have quite recently contributed a sum approaching 200,000*l.*; Yorkshire, by the establishment of the College of Science at Leeds, to which secondary schools of science are to be affiliated; the Company of Cloth workers, by the foundation of scholarships, and the endowment of a chair of textile technology in the Yorkshire College; the University of Durham, and the coal owners and manufacturers of the North of England, by their joint foundation of the School of Science at Newcastle; Oxford, by its patronage of the College to be established at Bristol; and the Company of Merchant Adventurers, by the aid which it is giving to the Trade School of the same city—are not only directly promoting the higher technical instruction among the populations in which their work is done, but will furnish competent teachers to the elementary and secondary schools of their own and other localities. I think there is no fear that a work of such national importance once so actively begun will suffer any relapse; but it will be in the power of this Association to promote by discussion and advice its intelligent and economical organization.

Owing to irregularities of surface, it often happens that considerable difficulty is encountered in putting a good polish on articles of brass or copper. If, however, they be immersed in a bath composed of aquafortis 1 part, spirits of salt 6 parts, and water 2 parts for a few minutes if small, or 20 or 30 if very large, they will become covered with a kind of black mud, which on removal by rinsing displays a beautifully lustrous under surface. Should the lustre be deemed insufficient, the immersion may be repeated, care being always taken to rinse thoroughly. All articles cleaned in this manner should be dried in hot dry sawdust.

MANUFACTURE OF PHOSPHURETTED STEEL RAILS AT TERRENOIRE.*

From "The Review of Mining."

M. Euverte, manager of the Terrenoire works, on being called upon by M. Jordan, the president, explained that he felt taken rather unawares in having to reply to the question that had been addressed to him. He feared that he should reply in an incomplete manner, and especially that he should not detail the facts in so systematic a manner as such a subject demanded.

But, on the other hand, he had attained on this question such an undesirable notoriety, such truly nonsensical things had been written and said of him, that, on this account, M. Euverte was not sorry to avail himself of the opportunity thus afforded him of placing matters in their proper light.

It was indeed true that during the last two years experiments on a grand scale had been made at Terrenoire, with a view to ascertain to what extent phosphorus might be introduced into steel; and these experiments had now yielded important, if not absolutely definite results.

But, in order to thoroughly understand the actual state of the question, it will be necessary to review rapidly all that has been done before, and to comprehend by what succession of ideas and investigations the present result has been obtained.

Every one who has, during the past ten years, kept up with the discoveries of metallurgical science, is quite in a position to understand that a considerable change has taken place on account of the grand discoveries of Mr. Bessemer and Mr. Siemens.

Since that period the manufacture of steel has been developed to a very large extent; and the day is not far distant when all the *materiel* of railways and works generally will be entirely of cast steel.

It must, however, be borne in mind that the present state of perfection has only been arrived at after many difficulties have been surmounted.

In the year 1856 Mr. Bessemer made the first experiments in connection with his process, when the results obtained were far from satisfactory. Nothing but a hyperoxidated iron, commonly called *over-burnt iron*, was turned out of the converter.

It was then that a large number of scientific men declared that this experiment was contrary to all known theories, and that the process would never succeed.

From 1856 to 1862 Mr. Bessemer prosecuted his investigations with that tenacity of purpose which is a characteristic of Englishmen; and, at the end of 1861, the learned French professor, M. Gruner, announced to the metallurgical world the complete success of the process.

What was it, then, that happened between the years 1856 and 1862?

Two very important matters were introduced into the ordinary practice of the Bessemer process.

The inventor had recognized the necessity of only making use in the converter of a gray pig, containing silicium or manganese, and also of adding a certain proportion of manganesian pig, called *spiegeleisen*, at the end of the operation.

The credit of the invention of the last portion of the process has been disputed with Mr. Bessemer. This is not a question to be gone into here; but what is very important to determine is that there is no doubt the addition of the *spiegeleisen*, or manganesian pig, has been the real cause of the ultimate success of the Bessemer process.

At that time no definite account could be given of the part played by the manganese in the process, and it was only after a longer period of practical experience that the action of the manganese became known, and was logically demonstrated. It is now universally admitted that the office of the manganese is to separate the oxide which is abundantly formed in the metal at the end of the Bessemer process.

It will, in fact, be easily understood

* Seance of the "Societe des Ingenieurs Civils."

that, under the action of a powerful blast, a considerable quantity of oxide of iron is formed, which interposes itself in the molten mass, and forms a decided obstacle to its malleability; it will also be understood that the manganese, the affinity of which for oxygen is well known, takes up this oxide of iron, so that the new compound mixes with the slag.

This practice of adding manganesian pig at the end of the converting operation has become invariable, and is applied not merely to the Bessemer, but also to the Siemens-Martin process.

When the Bessemer process was introduced into France the steel resulting therefrom was applied especially to the manufacture of rails, and this was the case for several years afterwards.

It will easily be conceived that the addition of a certain quantity of manganesian pig at the end of the operation had a double advantage, as far as the rails were concerned: on the one hand, the manganese fulfilled its important mission, which consists in separating the oxide; and on the other, the carbon contained in the *spiegeleisen* served to give the steel the durability suitable and desirable for the manufacture of rails.

But, after a certain amount of experience, another desideratum arose, which was to produce a very soft steel, to serve for the manufacture of plates, parts of engines, axles; in fact, all those portions of machinery which require to be made of a metal able to resist a blow.

Now, many attempts have been made to manufacture plates, etc., of steel that was more or less carburetted. But these attempts had never been successful, or, to speak more correctly, they had always been very unsuccessful. Serious accidents happened. Castings in a complete state were fractured in cooling, without its being possible to assign the cause of fracture; and finally it became necessary to exclude the carburetted steel in all cases which required a certain amount of malleability, or in which it was necessary to hammer the castings while hot.

On the other hand, it is evident to every one who knows the imperfections that exist in rolled plates and forgings of iron—imperfections which result from the necessity of there being several bands and weldings in the same piece—that the application of a cast metal to these articles offers a considerable amount of interest. There are, therefore, sufficiently weighty reasons for prosecuting this object by all possible means; and this is being done, with great perseverance, at the Terrenoire works.

The problem was, however, at first very difficult of solution; so the experimenters frequently found themselves in exactly the same position as that from which they started. In fact, when the operation is finished, manganese must be added to expel the oxide; but this very manganese introduces into the charge a certain quantity of carbon, which was contained in the manganesian pig.

If, for instance, in a charge of 3,500 kilogrammes (7,700 lbs.) of steel, 350 kil. (770 lbs.) of *spiegeleisen*, containing 9 per cent. of manganese and 5 per cent. of carbon, be introduced, 17 kil. (37½ lbs.) of carbon, representing about a five-thousandth part of the whole, will be introduced, thereby rendering the charge too highly carburetted to be malleable.

If less manganesian pig be added, the charge will contain, it is true, less carbon; but then the manganese will not be present in sufficient quantity, and the metal will be but slightly malleable. This is, then, a regular difficulty, out of which the only way to escape is by arriving at a mixture of metals rich in manganese, by which, without adding large quantities of carbon, a sufficient dose of manganese would be afforded. The production of a mixture rich in manganese was then found, *a priori*, the solution of one of the most important points in the progress of metallurgy. At the very moment that this solution of the question at the Terrenoire works was made known it happened, as has frequently been the case in the history of human industry, that in another place the problem was in a great measure solved. In fact, at this very time—that is to say, at the end of 1865—Mr. Bessemer made known to the Terrenoire Company the existence, in the neighborhood of Glasgow, of works producing a *ferro-manganese*, containing from 25 to 30 per cent. of metallic manganese, which had been obtained by the process of Mr. Henderson, the inventor. About the same time the German technical journals published the fact that a manufacture of ferro-manganese, by the process of M. Oscar Prieger, was es-

tablished at Cologne. The ferro-manganese produced at this establishment contained a uniform proportion of 75 per cent. of metallic manganese; it was made in crucibles, in a very slovenly manner, and was sold at 6 francs per kilogramme (about 2*s.* per lb.). Trials were made without the slightest delay at Terrenoire works, where these mixtures, which were found exactly to realize the desideratum before reasoned out; the results were exactly what one had a right to expect, and, especially with the ferro-manganese, a cast metal was obtained having all the qualities of the English homogeneous metal, containing but a slight trace of carbon, and lending itself remarkably well to all the uses of industry. The problem was solved in principle; but there was still much to do before arriving at a solution that was sufficient for manufacturing practice. In fact, for one reason or other, the manufacture was suspended in England; the price of the German spiegeleisen became much too high to be used with commercial success, and it would have been impossible to have procured the ferro-manganese unless the Terrenoire Company had come to an understanding with the inventors as to the right of founding a manufactory in France. This manufactory, definitely established in 1869, after many experiments and difficulties, has now got into thorough working order. The Henderson process, taken as the basis of operations, was brought to successive stages of improvement, and from the year 1871 ferro-manganese containing from 40 to 42 per cent. of metallic manganese has been produced at the Terrenoire works at the rate of 2 to 2½ fr. per kilogramme (9*d.* to 11½*d.* per lb.). Recent improvements will allow of the mixture to be produced containing as much as 50 per cent. of metallic manganese. The problem is now, therefore, thoroughly solved, and extra-malleable cast steel can be produced in a regular and satisfactory manner, suitable for the manufacture of plates, parts of engines, and military and naval ordnance, which can be used with safety, and which possess all the qualities that can be desired of resistance and elasticity. It thus happens that, at the present time, the State Marine requires, and also obtains, in large quantities, plates having a resistance to tensile strain of 45 to 50 kilogrammes per square millimetre (63,813 to 71,220 lbs. per square inch), and yielding to the extent of 20 to 25 per cent. before fracture.

The best brands of iron that are known have never given such results as the above; they are, besides, liable to the very great objections of piling and imperfect welding, so that no one will venture to deny that the production of a malleable steel possessing the properties above enumerated is one of the great achievements of modern metallurgical science.

M. Euverte here remarked that it might appear somewhat strange that in replying to a question relative to phosphuretted rails he should so far digress from the subject as to speak of the production of malleable cast steel by means of ferro-manganese.

He could not, however, avoid doing this, as the two questions were indissolubly connected, and he hoped to show that unless alloys rich in manganese had existed the phosphorus question applied to rails would still have been unsettled.

The investigations relating to phosphorus at the Terrenoire works date from a tolerably distant period.

At the end of the year 1869 one of the most distinguished leaders in the field of applied science in France, M. de Wendel, had undertaken some investigations on a large scale at Hayange, which were actively prosecuted, on the possibility of producing steel from ore extracted from the large mineral deposits of the Moselle, and containing a high percentage of phosphorus.

Pigs run under special conditions had been puddled with the greatest care, and the products thereof had been remelted in a Siemens-Martin furnace, and run into ingots for the manufacture of rails.

As M. de Wendel was not in possession of a set of rolls suitably arranged for the rolling of these steel rails, he entrusted the work to the Terrenoire Company.

This rolling took place in due course, and the result of the first attempt, imperfect though it necessarily was, gave the first indication that phosphorus was not entirely incompatible with steel, and that investigations in this direction should not be brought to a standstill on account of difficulties, real enough, it is true, but

which should not be absolutely insurmountable.

M. Euverte here stated that, personally, he had always been convinced that phosphorus need not be an absolute cause of inferior quality in steel, especially in the proportions he had mentioned in the first place.

In fact, it was well known to those who had studied the subject of iron manufacture in the different French districts, that the phosphoric irons were those which worked best in the rolls, and which best took any form it was desired to give them. These irons, it was true, especially in the form of rails, possessed a certain amount of brittleness when subjected to tests of impact; but this drawback had been much diminished by the progress in puddling and rolling during the last fifteen years, and no one would deny that phosphoric irons had entered the market to a considerable extent.

How, then, had it happened that, in the manufacture of cast steel, people had stumbled against such an absolute impossibility? How was it that the assertion had come to be made, that even the smallest proportion of phosphorus completely destroyed the malleability of steel?

Evidently there was here an unknown quantity to evolve; the particular causes had to be discovered which rendered phosphorus absolutely incompatible with steel, and this was one of those cases in which, given preceding experience, it might be said, "*Seek, and you shall find.*"

The experiments made on the cast steels produced at Hayange were the first result which showed that the object was not impossible to be attained; nor was it long before other trials more decisive took place.

For some years past, M. Tessié, of Motay, who was well known for his spirit of investigation and discovery, had undertaken, at Commines, Nord, some metallurgical experiments, with a view to eliminate the phosphorus from the pig. These experiments were ultimately transferred to Terrenoire, where they have been prosecuted up to the present time.

A conclusion was arrived at, however, which is often the case under similar circumstances, viz., that it is not so easy to get rid of the phosphorus by a rapid process, more or less analogous to that of Bessemer; but it was discovered, on the other hand, that under certain determined circumstances, the phosphorus incorporated with the steel produced no injurious effect.

On phosphuretted substances being introduced, in tolerably large proportions, into a Siemens-Martin furnace, and the operation being completed with ferromanganese, containing 42 per cent. of manganese, or rather with spiegeleisen, it was found that the metal obtained was malleable, and of good merchantable quality.

This experiment, resumed at different times, always yielded the same results; and it is from the result of a series of operations of this nature, that the following dictum has been arrived at by those conducting the investigations at Terrenoire:

Phosphorus may be introduced into cast steel, provided that the carbon be eliminated; and the less carbon there remains, the more phosphorus may be left.

This law, taken generally, is absolutely true at the present time, but it requires to be more precisely stated, so as to show positively the quantum of phosphorus which may be allowed to remain in a cast steel without impairing its essential qualities of malleability, resistance, etc.

Numberless experiments have been made with a view of arriving at these several particulars, and it is not yet possible to get out positive formulæ on the subject. For this reason it is much to be regretted that a premature publicity should have given to this question an aspect which it cannot really even now assume. People have even been induced to say and write that, by means of phosphorus, as good a quality of steel can be produced as any now in use, which is an assertion that must be met by direct denial.

That future experience will ultimately reveal valuable properties in steels containing phosphorus, is no doubt possible, and perhaps probable; but the question cannot be decided at the present time.

It must be allowed at once, that though it is desirable to be able to introduce phosphorus into steels, in order to utilize for their production raw products hitherto considered injurious, at any rate *as little as possible should be admitted.*

The result of all the experiments made

at Terrenoire is that the physical properties of the new metal thus obtained present peculiarities which merit an attentive study. The opinions formed thereon are not yet sufficiently definite to be put into form: but the subject of a future communication to the Association will be hereby afforded. For the present, M. Euverte must be content with observing that a field is here opened for research of great importance; and this is indeed an occasion to recall the words made use of by the learned President of the Association, during his inaugural speech: "*The sciences which may be called the molecular physics and mechanics of iron are indeed in their infancy.*" This is a great truth, and thanks are due to Mr. Jordan for having proclaimed its importance, and also for having drawn thereto the especial attention of metallurgists. That it is one of the departments of science and industry which are totally deficient in classified and reliable data, is admitted by all. The criterion of comparison is at fault in most cases, and a methodical investigation should be brought to bear upon this subject with a keenness of intellect with which few men are gifted. In fact, a specific talent for research should be developed and cultivated by each individual in and for himself.

The experience acquired by the numerous experiments on phosphoric steel already made at the Terrenoire Works, and those which are undertaken every day, keep alive in the most evident manner the importance of a study of the physical properties of metals. The results of the experiments will no doubt in time lead to more precise information; but all that can be stated at present, to keep within the bounds of strict veracity, is, that a steel containing about *three thousandth parts of phosphorus, and one and a-half thousandth part of carbon*, is very malleable, and may be used for the manufacture of rails of very good quality.

It may, perhaps, be said that a metal containing only *one and a-half thousandth part of carbon* is not steel. This is, perhaps, true, and it might be useful to raise the question if the nomenclature should not be modified, and whether it be well to retain the name *steel* for metals which contain scarcely any carbon, which do not become at all hard by being tempered, and resemble iron in every respect. The authorities of the navy have already given the name of *cast metal* (*métal fondu*) to the soft plates which they are now ordering in great quantity from the works of Terrenoire and Creuzot; and it may be asked whether it would not be well to adopt this term generally.

To sum up, it is now quite determined that cast steel may contain a certain proportion of phosphorus, without ceasing to be malleable, but at the same time retaining their valuable properties of resistance.

The precise proportions of phosphorus and carbon which may enter into the composition of a metal of good quality, and the different physical properties of this metal, will have to be definitely determined at some future time.

But we are now in possession of the principal fact, and also of this other fact, that a mixed metal, rich in manganese, can be satisfactorily produced; so that we may consider the problem solved, *that phosphorus may be introduced into the steel on condition that no carbon be added*, or at least with the addition of as little as possible of the last-named substance.

It would be difficult to foresee, positively, at the present time, what will be the ultimate consequence of the new facts which have just been detailed. It is not difficult to believe, however, that, taking the question in its broadest light, the results to be achieved may be very considerable.

One fact is, at any rate, evident to those who have followed the progress, not only of the metallurgy, but also of the world, during the last ten years, that a great change is taking place, by the gradual substitution of steel for iron.

It is equally certain that this change marks an actual progress, since the object is to replace a metal which is imperfect in its physical constitution, by another, which is stronger in every respect, and which, especially in the form of railway bars, has a durability from five to ten times greater, without an increase in cost proportionate to the advantage obtained.

But if the practice had been persisted in of only making use of first-class ores for the production of cast steel, the progress in question would have been considerably hindered.

In dealing with the question what would become of the old iron rails if all

the railway companies were to determine henceforward to use none but steel, no great amount of reasoning will be required to show that this course might give rise to serious difficulty.

If, however, it be proved that the old rails, judiciously mixed, can be recast and made into new, surely one is justified in considering that a great problem has been solved, since it renders easy of accomplishment a change which all are agreed is desirable.

But if, especially, it be calculated that the old rails are now represented by the following figures: France, three million tons; England, six million tons; America, ten million tons; and the rest of the world, ten million tons—that is to say, at least *thirty million tons of rails made of bad iron, which might be turned into cast steel rails*—the importance of the result at which it is possible to arrive by applying the principles enunciated above, is still more striking.

There is still one other consequence arising from these new discoveries, which is not without importance, and which deserves to be taken into serious consideration. Since the Bessemer and Siemens-Martin processes have come into common use, great quantities of cast steel have been turned out under different forms; but no matter to what use they have been put, rails, plates, axles, parts of engines, or what not, the same class of ores has always been employed, and always those of superior quality. It is this circumstance which caused the learned and lamented Rivot to say: *It is contrary to commercial common sense to make rails out of Mutka ore.* This is perfectly true; but up to the present day, one had reason in replying to M. Rivot: One does as one can.

From the present time, however, these conditions will be considerably modified. A classification of ores will be made, and each will be applied to the purpose for which it is best suited. The different samples of cast steel will also be classed according to their quality, as is now the case with the different brands of iron; and when this is done it will be possible to say that metallurgical practice has been placed upon a rational basis, and that it is in a position to turn to best account all the elements at its disposal.

During the discussion which followed this valuable communication, the President, referring to the publicity of which M. Euverte complained at the beginning of his speech, asked if it were true, as was reported, that some railway companies had already received several thousand tons of cast steel rails containing three or four thousandth parts of phosphorus. Also, if cast steel had been produced from phosphoric ores so as to justify the expectation of certain metallurgists who already see the centre of the steel manufacture in France transferred from the basin of the Loire to that of the Moselle.

M. Euverte replied that the quantity of rails cast from old *materiel*, and supplied to the railway companies, had been greatly exaggerated; that in the manufacture, those old rails had been chosen which offered the least difficulty in the process; and that even if true, that metal containing four millionth parts of phosphorus has been rolled into rails (which were however brittle), the rails sent out were far from containing this proportion of phosphorus. Steel had not yet been produced from phosphoric ores, but the speaker was not without hopes of seeing this brought about. He added that the important point, one which required steady application in order that sound progress might take place in their working, was the molecular condition of the new kinds of steel, which presented some strange phenomena hitherto unexplained.

M. de Hastaing asked how the old rails were treated in this process.

The President believed he was able to answer this question; it was by means of the Siemens-Martin furnace. In order to carry on the discussion he then remarked that the advantageous employment of phosphoric irons, in rails which were piled and welded, was a well-known fact: as, for instance, the rails of the Moselle, of the Ruhr, and other places. Karsten, who may be regarded as a classic writer on metallurgy, said that irons may be applied to certain purposes if they contain three, and even five millionth parts of phosphorus.

The Terrenoire Company appeared to have found means, thanks to ferro-manganese, of working up welded phosphoric rails, and converting them into cast phosphoric rails; and this was a considerable step in metallurgic progress.

Of course the question was not one of

designedly introducing phosphorus into the steel, but of turning to account what one was obliged to leave therein.

The presence of manganese in certain samples of steel was regarded by distinguished metallurgists in a favorable light, inasmuch as they attribute both malleability and elasticity to its presence.

As regards the definition of steel, the President had long been of opinion that the word should only be applied to malleable cast metal, and that it might be used for all metals of this class. He saw no greater difficulty in designating by the same name the fine steels of Dannemora, and the new class of steels of Terrenoire, than in including under the general name of *iron* the Swedish wire for the teeth of cards and the soft iron of the Moselle, or under the general name of *pig* iron the black Scotch pig, and the German spiegeleisen. The art of the engineer and the metallurgist consisted in knowing exactly how to turn to its proper account each class of matter.

M. Euverte was entirely of this opinion, and regretted that a mischievous publicity had attributed to phosphoric steel all possible qualities.

As to the introduction of phosphorus into the metal for making steel rails, this cannot be avoided when it is required to work up old rails. When old phosphoric rails are added to a charge consisting from the first of a considerable quantity of good metal, the mixture cannot fail ultimately to contain some portion of phosphorus; but in order to have as little of this substance as possible, the speaker, if he had to work up all the old rails of all the French railways, for instance, would contrive the mixture so as to reduce the phosphorus to a minimum.

As regards the question of malleability, the greatest enemy of which is oxidation, M. Euverte considers that the office of manganese is especially to counteract the oxidation or to dispel the oxide.

The President, in conclusion, thanked M. Euverte for his important and very interesting communication, and begged him not to forget that he had promised to continue it at some future time.

FOUNDRY CRANES.

From "Iron."

It is the author's opinion that less is known, and much less done, in the arrangement of the lifting power, as applied in a foundry, so as to meet the especial requirements thereof, than in any other department of the engineering and iron trade. Generally speaking, foundries are so ill constructed, that to erect therein a proper system of lifting power is almost out of the question. Very often foundries are made up of shreds and patches of buildings, so ill adapted for their purpose that it is almost impossible to erect therein anything like a proper foundry crane, and all sorts of strange erections are fixed in them, and only do the mimimum amount of duty, with a maximum amount of power. This not unfrequently happens from the idea that any person can construct and manage a foundry, without thoroughly understanding the principles of the art of founding, or yet a correct knowledge of the laws of mechanics.

When we first went into a foundry nearly half a century ago the old cranes had ropes instead of chains; and such was the aversion to the use of chains on cranes at that time that you could hardly induce a sand moulder to lift his mould with them for fear of shaking his mould to pieces, so unsteady were the then existing cranes that had chain falls upon them. And when we look back at the strange pieces of rude mechanism that had to do duty for foundry cranes we do not wonder at the moulders of that day objecting to use chains, or clinging so tenaciously to ropes; and yet rope falls had serious drawbacks, for they had to suspend underneath the bottom block a sheet iron cover to keep the heat of the molten iron in their crane ladles from burning the ropes. But from the various accidents daily arising from those old-fashioned cranes, and the ever-increasing demands for larger castings through the rapid progress of engineering, much pro-

gress has been made in improving the jib cranes by making them to wind the blocks out and in to any radius, so that they could lift a mould or casting at any point within the radius of the cranes. Many of the arrangements were then very imperfect, but others succeeded of a more admirable description, yet all had to be worked by hand power. Subsequently steam power was applied to them, in some cases by connecting the working gear to the main shafting of the engine. Getting power by this method was a great convenience, because it was less expensive, more powerful, and did a much greater amount of useful work. But power thus applied was found not sufficiently accurate for a foundry, or to meet the ever-varying requirements of moulding. Subsequently small steam engines were fixed to the cranes, which enabled the engine man to execute any movements as to speed, stopping, or reversing, as were required. Many of these cranes are excellent, but some of them are far otherwise.

Another motive power also has been applied to jib cranes, and that is Sir William Armstrong's system of hydraulic power; and for ease, precision, and rapidity of motion I consider the system to be in the foremost rank as to arrangement of jib cranes for the use of a foundry. Such cranes are very costly in their construction, no doubt will require a good deal of keeping in repair, must be repaired with skill, and are not always suitable for every foundry, but they are worthy of admiration. Small steam cranes can more easily be applied in many cases, and can either get their steam from a fixed boiler on the works or a small one attached to the crane.

Another description of crane has come much into use in foundries, and that is the overheard travelling crane. It has many advantages over the jib crane, especially in large foundries. It, in the first place, does not take up any of the available space on the shop floor as a fixed crane does; it has a much wider range of usefulness, having the extreme length and breadth of the building, whereas a jib crane can only be useful within the limit of its own circle, and a great portion of that is lost near the centre; and also it does not require, as in a large shop, to change the load from one crane to another. At first overhead cranes were very imperfect, simply comprising a pair of traversing beams and a common crab for lifting on the top; but in course of time the arrangements were so much perfected that all the motions were directed by one man, and were made to work with great accuracy. The very imperfect ones may be passed over. Some have been modified. For instance, they have been worked from the floor by means of endless chains so that men might not be on the top of the crane; but they were not a success, as they wanted all the elements of a useful foundry crane—ease, regularity, and rapidity of motion. There was another where all the motive power was applied by the men from a small hanging platform under one end of the beams; and for a hand-power crane much could be done thus wise. But the best hand-power overhead trailing cranes seen by us especially adapted for a foundry were designed by Mr. D. Thompson, when manager to Messrs Simpson and Co., of Pimlico, London; these have all the requirements of a real foundry crane worked by hand.

The next thing was the application of steam power under various modifications to overhead travelling cranes. In some instances this was effected by applying the power from a fixed engine, and working the shafting and bevelled gearing with the machinery; but this method is not suitable for a foundry, as it is wanting in the element of making the motions at any rate of speed required with precision. Another method, which has been, and is now, very much in use, is by an endless rope running at a very high velocity, worked by a fixed engine, and by the contact of friction shears producing the various motions. This system also has many drawbacks, the greatest being the amount of wear and tear upon a rope running at such a great speed. Although the arrangements of this system have many modifications, yet none that we have seen fully meet the requirements of a foundry; for one cannot obtain the ever-varying amount of speed in all its changes as required, or stop or start suddenly any motion that may be needed. We have well tested them, but they are not to our mind a perfect foundry crane.

The most complete steam travelling

crane for a foundry we have seen was made by Messrs. J. and H. Ellis, of Salford, Manchester, for the foundry of the Fairbairn Engineering Company, Manchester; it has a pair of 6-in. cylinder engines and boiler attached to it at one end of the beams, and all under the control of the engine-driver; and for accuracy of work, ease, and rapidity, we have seen none to equal it. In some of the details of arrangements, improvements no doubt can be made, but the principle upon which it is constructed, as far as our own experience is concerned, justifies the highest commendation.

ON THE USE OF STEEL RAILS, AND THE NEW CLAUSES IN THE SYSTEM OF TESTING IN RUSSIA.

From the "Universal Review of Mining."

THE rapidity with which the system of Russian railways has been completed has latterly raised the question of the use of steel rails instead of iron ones for the new lines. This question has been decided in favor of the former; for the Russian Imperial Administration has approved of the construction with steel rails of the railways from Wjasma to Tula, Rjask, and Jeletz, and from Morschansk to Siezran, comprising a length of 1,200 kilometres.

The ministry of finance fully guarantees the preference shares of these railways, amounting to three-fourths of the entire capital, as also, for a term of fifteen years, the remaining shares, forming one-fourth of the capital. This circumstance evidently proves that the government regards the use of steel rails as highly advantageous, notwithstanding it involves an additional payment to the contractor of 1,023 roubles per werst.

It is astonishing that in other countries, especially in Austria and Germany, where the traffic is more considerable than in Russia, the same conclusion has not been arrived at. We are convinced that the adoption of the same measures in these countries would diminish the subsidies that have to be paid out of the public treasury.

The weight of the steel rails for the new Russian railways is 26.88 kil. per current metre. These rails are intended to replace iron ones weighing 32.26 kil. per current metre.

After a long discussion, there has been adopted, as a type, one of Vignoles' rails, which is 107.95 millimetres high, 95.25 millimetres wide at the foot, and 12 millimetres thick in the middle.

The measurement adopted is a difficult one to roll; but it is convenient in this respect, that it admits of the rails being solidly fished. The length of the rails has been fixed at 24 English feet. With a view to their transport, it is only after some hesitation that it was decided to give them this length, seeing that the normal length of the Russian vehicles is only 21 English feet, or about 24 feet including the buffers.

Moreover, it is always more economical for railway managers not to order short rails, as the net cost per ton is much higher for rails of moderate weight, in keeping to the ordinary length of 21 feet. For this reason, the Americans, who are practical men, have given to light rails a length of from 27 to 30 feet.

Fixing the standard of the test system has also given rise to serious observations, especially with respect to tests. The Commission, which was composed of the most experienced railway engineers, decided, after long debates, that steel rails, weighing 26.88 kil. per current metre, should stand the following tests:

1*st Test.*—The rail, placed on supports 3 feet apart (0.912 metre), and bearing for five minutes a weight of 16½ tons, ought not to give way more than 0.15 of an inch (3.75 mil.). After withdrawing the load, the permanent bend should not exceed 0.04 of an inch (1 mil.).

2*d Test.*—The rail, placed on supports 3½ feet apart (1.06 metre), should bear, without breaking, the shock of a batter-

ing ram of half a ton, falling from a height of 9¾ feet (2.96 metres).

Iron rails of 32.26 kil. per current metre were subjected to the same tests, but only with half the loads and weights.

We applaud these results; they prove, we think, that in Russia technical men have examined the question conscientiously and profoundly.

It is necessary to observe that the climate of Russia requires rails of greater solidity and resistance than those used in other countries.

It has been thought, during late years, that the maximum of resistance would be obtained by subjecting the rails to the test of a tremendous shock; but experience has shown that both iron and steel rails, which had borne the test with ease, and had broken very little in being used, lasted only a short time in consequence of their hardness.

For this reason, the test of the shock which was formerly applied, of letting a battering-ram weighing 1,000 kil. fall from a height of 5 metres, has been reduced to 5 per cent. for rails of 28 kil. per current metre. A corresponding reduction has been made for lighter profiles.

The flexion test appears to us to be safer than that of the shock. The French records contain more rational rules in this respect, containing, as they do, a certain number of strokes, falling from a different height, which determine at the same time the maximum of flexion. By this means, rails of sufficient hardness are sure to be obtained, whereas it is to be feared they may be got too soft in subjecting them to a violent concussion without indicating the arc of flexion.

Steel rails have answered well in Russia.

The Nicolas railway, on which the greatest number has hitherto been employed (96,000 rails), after three years' service, shows a maximum refuse of 0.87 per cent., and a minimum of 0.03 per cent. This result is all the more remarkable as the Nicolas railway (a double line) yields a daily revenue of 182 francs per kilometre; it may therefore be ranked among those possessing the largest traffic in the world.

A question not less important for the solidity of steel rails, is the position of the notches in which the fastenings of the rails have to be inserted. It will be interesting to show the results obtained by careful experiments relative to the resistance of steel rails notched in different ways.

These results show what a considerable influence the position of the notches has upon the resistance of the rails. Railway managers should give their special attention to this point, because a large proportion, we may say the largest proportion, of rail fractures arises from the position of the notches.

EXPERIMENTS ON THE RESISTANCE OF STEEL RAILS DIFFERENTLY NOTCHED, ON THE PARIS AND LYONS RAILWAY.

Trials by shock on Rails with or without notches with a hammer of 300 kil.

Dates.	Bessemer Steel.	Height of fall determining the rupture.
	Steel Rails, with two pentagonal notches:	
1871.		Metres.
July 24.	Notched with a drilling machine.....	0.256
" "	Do. do. and filed..	0.300
" 28.	Without notch.....	2.500
" "	Notched with a drilling machine.....	0.350
" "	Do. do. and filed..	0.600
" "	Without notch.....	3.000
	Steel Rails with only one semi-circular notch:	
July 28.	Notched with a cutting file.....	0.500
" "	Without notch.....	4.000
Aug. 10.	Notched with a drilling machine.....	0.500
" "	Do. do. and filed..	0.550
" "	Without notch on a length of 5.96 met..	3.620

Average Resistance:

	Without notch.	Notched with a drilling machine.	Notched with a drilling machine and filed.	Notched with a cutting file.
Steel rails with two pentagonal notches.....	2.75	0.30	0.45	....
Do. with a single semi-circular notch.....	3.96	0.50	0.53	0.90

From these results it is evident that steel rails, when notched, present a much more feeble resistance to the shock than rails without notches, or than those only notched at one end.

We may say, in conclusion, that in 1872, 70,000 tons of steel rails were ordered for Russian railways. The Creusot manufactory has had the lion's share of this order, which had to be delivered in 1873–'74. It forms a new outlet opened to this manufactory, which will probably be durable, seeing that English manufacturers do not care to make rails whose weight, as is the case here, does not exceed 26.88 kil. per metre.

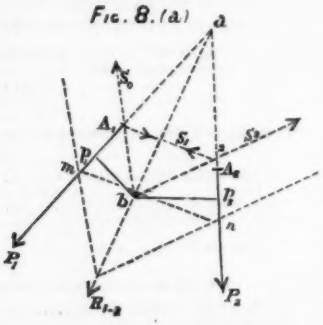
THE NEW METHOD OF GRAPHICAL STATICS.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.
By A. J. DUBOIS, C. E., PH. D.

CHAPTER II.

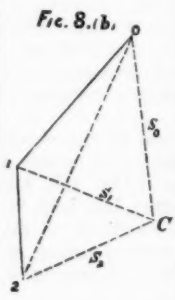
FORCES LYING IN THE SAME PLANE—DIFFERENT POINTS OF APPLICATION.

16. RESULTANT OF TWO FORCES IN A PLANE—DIFFERENT POINTS OF APPLICATION. Heretofore we have considered forces having a common point of application, and have seen that in any case the direction and intensity of the resultant is easily found by *closing the force polygon.*



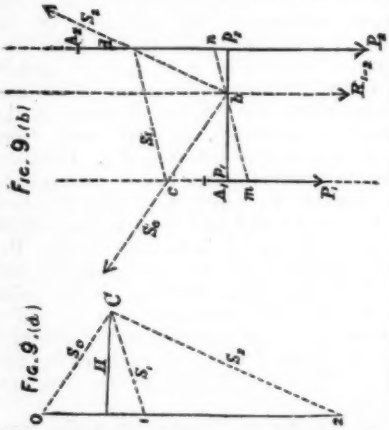
But suppose we have two forces P_1 P^2 having *different* points of application A_1 A_2; required the position and direction of the resultant [Fig. 8]. *Any force acting in a plane may be considered as acting at any point in its line of direction.* P_1 and P_2 may then be supposed to act at their common point of intersection a_1 and through *this* point the resultant should psss. The case reduces therefore to a common point of application. The resultant is given in intensity and direction by the force polygon (*b*) and its position is determined by the point of intersection *a*. At this point, or at *any point* in the line through *a*, parallel to 0 2, the resultant may be supposed to act.

But the direction of the forces may not intersect within reasonable limits, or the forces may be supposed parallel to each other, so that they *may not intersect at all.* In any case the *force polygon* will give the intensity and direction of action of the resultant, but its position in the plane of the forces remains to be determined. We have seen [Art. 5] that we can decompose a force into two components in any desired directions, by choosing a "*pole*" and drawing lines to the beginning and end of the force in the force polygon. Let us choose then a *pole* C [Fig. 8 (*b*)] and decompose the resultant thus into two forces given in intensity by 0 C and 2 C. The forces P_1 P_2 being supposed to act at the points A_1 A_2 in the common plane, at what point in the plane and in what direction must the resultant be applied to keep this plane and hold the forces in equilibrium? The direction of action of the resultant is given at once from the force polygon [Art. 5 (*b*)]. It must act in a direction from 2 to 0, and must be equal to 2, 0, taken to the scale of force. Now at *any* point in the line of direction of P_1, as for instance A_1, let us suppose the component given by C_0 to act. What is the resultant of P_1 and C_0? A glance at the force polygon gives us 1 C, because this line closes the polygon made by C_0 0 1 and 1 C. At A_1 then the three forces S_0 (parallel and equal to C_1) S_1 (parallel and equal to 1 C) and P_1 are in equilibrium, and there is no tendency of the point A_1 to move. But 1 C or S_1 may be considered as acting in the plane at *any* point in its line of direction; therefore at 2 its intersection with P_2 prolonged. Suppose at 2 S_2 or 2 C to act. We see at once from the force polygon that 2 C C_1 and P_2 are in equilibrium. There is therefore no tendency for the point 2 to move, and the two forces P_1 P_2 are then in equilibrium with C_0 1 C C_1 and 2 C. But since the resultant of C_0 and 1 C or of S_0 and S_2 is also the resultant of the forces, and since it must moreover act throughout the point of intersection of S_0 and S_2; we have only to prolong these lines to inter-



section *b*. Through this point the resultant $R_{1\text{-}2}$ must pass and acting *downwards* (from $_0$ to $_2$) as indicated in the Fig., it *replaces* P_1 P_2. Acting upwards it would hold them in equilibrium. We thus easily find the point 2 in the plane at which 2 C or S_2 must be applied, *when* C_0 or S_0 *acts at* A_1, and S_0 S_2 are thus found in proper relative position. The position, intensity, and direction of the resultant are thus completely determined.

Had we taken any *other* point than A_1, as the point of application of C_0, we should have found a different corresponding point for application of 2 C, but in any case the prolongations of 2 C and C_0 would intersect upon the line *a b*, prolonged if necessary. The same holds true for any position of the "*pole*" C. This construction is evidently general



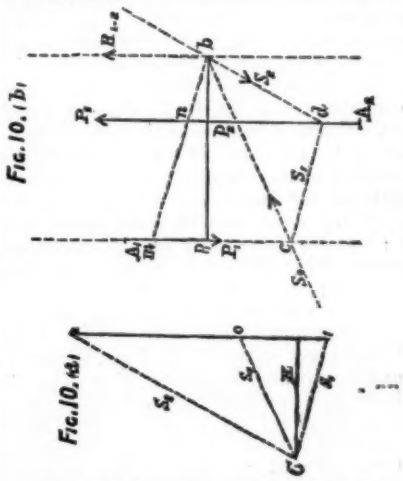
whatever the position or whatever the number of the forces. We thus obtain a number of points along the line *a b;* that is, the resultant also may act at any point in its line of direction.

[NOTE.— *That b is a point in the resultant of* P_1 *and* P_2 *can be proved in a method purely geometrical. In the two "complete quadrilaterals"* 0, 1, 2, C, *and* A_1 *b* 2 *a the five pairs of corresponding sides* 0 1 *and a* A_1, 1 2 *and a* 2, 2 C *and b* 2, C_0 *and b* A_1, C 1 and A_1 2, *are parallel each to each, therefore the sixth pair* 0 2 *and a b must also be parallel; b is therefore a point of the resultant passing through a, parallel to* 0 2.]

17. THE ABOVE CONSTRUCTION HOLDS GOOD EQUALLY WELL FOR PARALLEL FORCES. By means of it we find in Fig. 9 (*a*) and (*b*) and Fig. 10 (*a*) and (*b*) the resultant of a pair of parallel forces, in the first case, both acting in the same direction; in the second, in opposite directions.

In both cases we have simply to choose a pole C, and draw S_0 S_1 and S_2. Then taking any point *c* in the line of direction of P_1, as a point of application for S_0, draw through this point S_1, thus finding *d*, the point of application for S_2. S_0 and S_2 prolonged, intersect upon the resultant, whose intensity, direction, and position thus become fully known.

18. PROPERTY OF THE POINT B. It is plain that thus a point of intersection *b*, through which the resultant must pass,



can always be found, provided S_0 and S_2 do not fall together in the force polygon, or intersect without the limits of the drawing. By properly choosing the position of the pole C, this can always be avoided if the points 2 and 0 in the *force polygon do not themselves coincide.*

The point *b* Figs. 8, 9, and 10 which by reason of the arbitrary position of the *pole* may lie anywhere upon the resultant, has a remarkable property. If we draw a line *m n* through this point parallel to S_1, and let fall from it perpendiculars p_1 and p_2 upon P_1 and P_2, then in all three cases and therefore generally, the triangle *c m b* is similar to 0 C 1, and *d b n* is similar to 1 C 2. Hence we have the proportions—

$$0\,1 : 1\,C :: c\,m : m\,b, \text{ and}$$
$$1\,C : 1\,2\,n :: b : n\,d.$$

From these proportions we find

$$0\,1 : 1\,2 :: c\,m \times n\,b : m\,b \times n\,d.$$

Now the triangles $c\ m\ b$ and $d\ n\ b$, have the same height above the base $m\ n$; the bases $m\ b$ and $b\ n$ are therefore proportional to their areas. But their areas are equal to their sides $c\ m$ and $n\ d$ multiplied by p_1 and p_2 respectively. Hence we have from the above proportion—

$$0\,1 : 1\,2 :: n\,d \times p_2 : n\,d \times p_1 \text{ or}$$
$$0\,1 : 1\,2 :: p_2 : p_1$$

That is, *the perpendiculars let fall from any point of the resultant upon the components, are to each other inversely as the components.* Regarding any point of the resultant as a centre of moments, the moments of the forces then are equal, and of course the forces themselves are inversely as their lever arms.

19. Equilibrium Polygon.—If we consider the forces $P_1\ P_2$, Figs. 8, 9 and 10, held in equilibrium by their components C_0, 1 C, and 2 C, C 1, which act parallel to the lines $S_0\ S_1$ and S_2; then regarding the line S_1 or $c\ d$ as part of the material plane in which the forces act, C 1 and 1 C balance one another, and cause either tension or compression in $c\ d$. Suppose the resultant R is to act so as to cause equilibrium, or prevent the motion of the plane due to P_1 and P_2. Then R must act upwards in Figs. 8 and 9, and downwards from 2 to 0 in Fig. 10. In Figs. 8 and 9 then, S_0 and S_2 act *away* from c and d (Art. 4), and in Fig. 10 *towards* c and d. Following round the force polygon, we find in the first two cases $c\ d$ in *tension*, in the last $c\ d$ in *compression*.

In the first two cases, the points of application c and d of $S_0\ P_1$ and $S_2\ P_2$ if connected by a *string* stretched between c and d will be perfectly fixed and motionless; while in the latter case, the string must be replaced by a *strut*. In case of three or more forces the polygon or broken line which we obtain, by choosing a pole, drawing lines to the beginning and end of the forces in the force polygon, and then parallels to these lines intersecting the lines of direction of the forces in the *force diagram*, we call the "*string*" or "*funicular polygon*," or the "*strut polygon*," according as the forces act to cause tension or compression along these lines. We can apply to both cases the general designation of polygon of equilibrium or "*equilibrium polygon.*" The perpendicular let fall from the pole C *upon the direction of the resultant* in the force polygon, we call the "*pole distance*" and shall always designate it by H. The straight line joining the points c and d, or the beginning and end of the equilibrium polygon, we call the "*strut*" or "*tie line*" or generally the "*closing line*" and designate it by L. The convenience and application of these terms and conceptions will soon appear. In the present case of only *two* forces, the equilibrium polygon becomes a straight line and coincides with L, or $c\ d$.

[Note.—We repeat that in order to determine the *quality* of the strain in $c\ d$, we have only to follow round the force polygon in *the direction of the forces*, and then refer to the force diagram. Thus Fig. 9, at c, $P_1\ S_0$ and S_1 act, and are in equilibrium. The corresponding closed figure is given in the force polygon (a). S_0 acts away from c, P_1 acts downwards from 0 1. Continuing this direction we find S_1 acting from 1 towards C. *Reversing* this direction (Art. 4), we find that the resultant which *replaces* S_0 and P_1 acts from c to 1. Referring now to the force diagram (b), and transferring this direction to the point c, we find this resultant acts to pull c *away* from d or *contrary* to the direction of the force 1 C which replaces S_2 and P_2. The strain in $c\ d$ is therefore tension.

A better way of arriving at the same result, is to consider the triangle $c\ b\ d$ as a jointed *frame* which holds in equilibrium the forces $P_1\ P_2$ and $R_{1,2}$. Then the strains in any two pieces $c\ d$, $c\ b$, meeting at a point, *are in equilibrium with the force or forces acting at that point.*

We have then the force P_1 acting at apex c, decomposed into strains along $c\ b$ and $c\ d$ (Art. 5) represented by C_0 and 1 C in the force polygon. All three are in *equilibrium*. P_1 acts *down*. Follow *down* then from 0 to 1 from 1 to c and c to 0. Refer back now to apex c of the frame and transfer these directions. The strain in $c\ d$ acts *away* from the apex c and is therefore in tension, while

the piece *c b* would be in compression, since the direction of C_0 is *towards apex c.*

See also "practical applications" of the preceding chapter for illustrations of this.

In the same way follow round 0 1 C Fig. 10 (*a*) and refer to (*b*) and S_1 is in *compression.*]

20. Case of a Couple.—In Article 18 we remarked that the pole can always be chosen in such a position as to give S_0 and S_2 intersecting within desired limits, *provided* that S_0 and S_2 or the point 0 and 2 do not *coincide.* This case however actually happens, with a pair of equal and opposite forces—that is, with a *couple.*

Thus in Fig. 11 we have two equal and opposite forces P_1, P_2.

The force polygon closes: therefore the resultant is zero. S_0 and S_2 are parallel, hence their point of intersection in the equilibrium polygon is infinitely

Fig. II. (a)

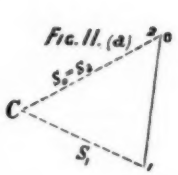
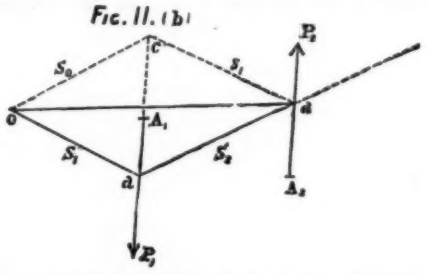


Fig. II. (b)



distant. By changing the position of the pole, we see that S_0 and S_2 may take *any* positions in the plane.

Two forces therefore which form a couple *cannot be replaced by a single force.* Their resultant is an indefinitely small force situated in any position in the plane of the forces, at an infinite distance.

Conditions of Equilibrium.—If then, similarly to Art. 4, any number of forces lying in the same plane and having different points of application, are in *equilibrium*, the force polygon always *closes.*

But inversely, if the force polygon closes, *it does not follow that the forces are in equilibrium*—a couple *may* result.

To determine whether this is the case inspect the "equilibrium polygon." If this *also closes* [*i. e.*, if S_0 and S_2 intersect] the forces are in equilibrium. If this does *not* close [*i. e.*, if S_0 and S_2 are *parallel*] there is no single resultant, but the forces can be replaced by a *couple,* and this couple, as we have seen, may have *any* position in the plane.

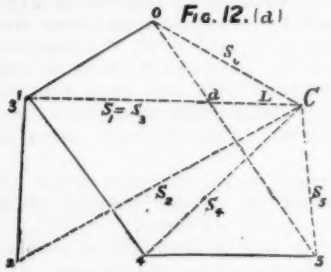
21. Thus if we suppose in Fig. 11, P_1 and P_2 decomposed into their components S_0, S_1, and S_1, S_2, the compressive strains in S_1 at *c* and *d* are equal and opposite [see (*a*)]. We have then S_0 and S_2 remaining which again form a couple which must have the same action as the first.

Hence we see that *one couple can be replaced by another without changing the action of the forces.*

It is easy to determine a simple relation between any two couples. If from *c* we lay off *c a* equal to *o* 1, and *c o* equal to C_0, we have *o a* parallel to C_1 or S_1, and therefore to *c d.* Join *a d* and *o d.* The triangles *c d a* and *c d o* having a common base *c d* and their vertices *o* and *a* in a line parallel to *c d*, are equal in area. The side *c a* of one is known, and the opposite apex lies in the line of the force P_2. Its area is then *c a* $= P_1$ multiplied by half of the perpendicular distance of P_1 from P_2, and is therefore completely determined. So also for the other triangle, one side of which *o c* is one force of the new couple, and the opposite apex of which lies in the other force S_2.

Hence—*a couple can be turned at will in its plane of action, and the intensity and direction of its forces can be changed at will if the area of the triangle the base of which is one of the new forces, and whose opposite apex lies in the other force, is constant; or when the product of the intensity of the forces into their perpendicular distance remains the same.* The direction of rotation, of course, must also remain the same.

We shall see further on the significance of this area, or of this product—so much is clear, that a couple (or infinitely small, infinitely distant force) is completely determined in its plane when the direction of rotation is given, and the



area of the triangle or value of the product to which it is proportional, is known. The couple itself can be replaced by any two parallel equal and opposite forces whatever, if only the triangle having one force as base, and the opposite apex in the other, has a given constant area.*

22. Force and Equilibrium Polygons for any Number of Forces in a Plane.

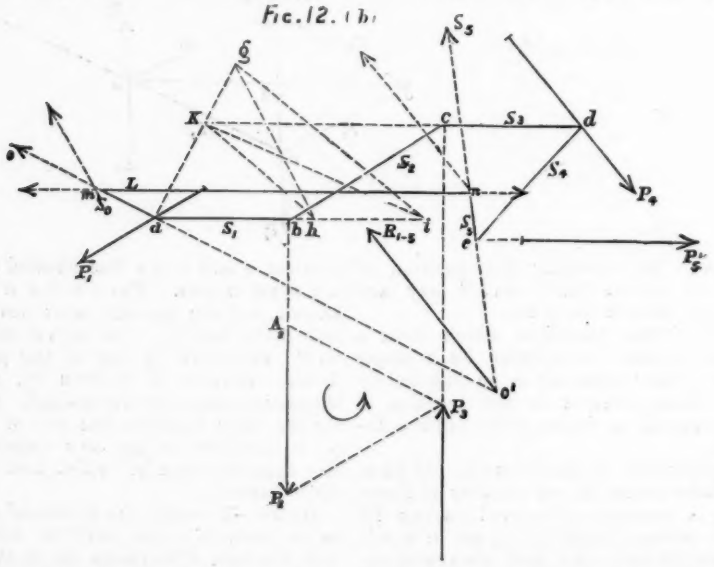
In Fig. 12 (*b*) we have the forces $P_{1\text{-}5}$ acting in various directions and at different points of application. P_2 and P_5 form a *couple;* that is, are equal, parallel, and opposite in direction. Required the position, intensity and direction of action of the resultant.

First, form the *force polygon*, Fig. 12 (*a*), by laying off the forces to scale one after the other in proper direction. Thus we have 0 1, 1 2, 2 3, 3 4, 4 5 in Fig. 12 (*a*) parallel respectively to P_1 P_2 P_3, etc., in Fig. 12 (*b*). The line necessary to close the polygon, 0 5, is the resultant in intensity and direction. In intensity because the length of 0 5 taken to the scale of force, gives the intensity of the resultant; in direction because acting from 5 to 0 it produces equilibrium, while acting in the opposite direction, from 0 to 5, it replaces the forces.

We have, therefore, only to find the *position* of the resultant in the plane of the given forces in Fig. 12 (*b*). Hence:

Second, choose a "*pole*" as C, and

Fig. 12. (b)



draw the line or rays, or "*strings*" S_0 S_1 S_2 S_3 S_4, etc. S_0 and S_5 are evidently components of the resultant, since they form with it a closed figure in the force polygon.

Third, form the *equilibrium polygon* *o a b c d e o'*, Fig. 12 (*b*), as follows:

*Elemente der Graphischen Statik. Bauschinger. Munchen. 1871. Pp. 11, 12.

Draw a line parallel to S_0 intersecting P_1 (produced if necessary) at any point as *a*. From this point draw a line parallel to S_1 to intersection with P_2 (also produced if necessary) at *b*. From *b* parallel to S_2 to *c*, then parallel to S_3 to *d*, and finally parallel to S_4, to intersection *e* with P_5. Through this last point draw a line parallel to the last ray S_5. Now S_0 and S_5 are components of the resultant 0 5 [Fig. 12 (*a*)] and are found in proper relative position. Produce them, therefore, to intersection 0′. Through this point the resultant must pass. Drawing them through 0′, a line parallel to 0 5, we have the resultant in proper position, and acting in the direction indicated in the figure, it produces *equilibrium*.

Any other point than *a*, upon the direction of P_1, assumed as a starting point, would have given a different point 0′; so also for any other assumed position of the *pole* C. But in every case we shall obtain a point upon the line of direction of $R_{1\text{-}5}$ already found. The reader may easily convince himself of this by making the construction for different poles, and points of beginning, and a little consideration will make the reason apparent.

Now the polygon or broken line, *a b c d e*, we call the *equilibrium polygon*—that is, *it is the position which a system of strings or struts, S_0 S_1 S_2, etc., would assume under the action of the given forces at the assumed points of application.*

Thus P_1 acting at *a*, is held in equilibrium by the forces along S_0 and S_1, P_2 acting at *b*, by S_1 and S_2 and so on. If we join any two points in the line of direction of S_0, and S_5, as *m n* by a line, we have then a *jointed frame*, which acted upon at the apices *a . . .e* by the forces $P_1 . . . P_5$, and at *m* and *n* by S_0 and S_5 is *equilibrium*.

For S_0 acting at *m*, we see from the force polygon may be *replaced* by a force *a o* parallel and opposed to the resultant R and a force C *a* acting along the line L. In like manner S_5 may be *replaced* by *a* C and 5 *a* parallel and opposed to the resultant. The two forces *a* C and C *a* being equal and opposed balance each other through *m n*, while the sum of *a o* and 5 *a* is equal and opposed to the resultant 0 5. There is, therefore, equilibrium, and *m* and *n* may be considered as the *points of support* of the frame acted upon by the forces $P_1 . . . P_5$ at the apices *a . . .e*, *a o* and 5 *a* being the upward *reactions* at the points of support.

As to the *quality* of the strains in the different pieces, as before the reaction at *m*, viz., *a o*, is in equilibrium with the strain in *m n* and *m a*. Following round, then, in the force polygon from *a* to *o*, *o* to C and C to *a*, and referring back to the *frame*, we find strain in *m n* acting *towards* apex *m*, therefore *compressive*; strain in *m a* acting *away* from *m*, therefore *tensile*. In like manner S_1 S_2 S_3 are in tension, while S_4 or *d e* and S_5 or *e n* are compressed.

Hence we may *fix* any two points of the equilibrium polygon by joining them by a line. The forces acting at these points are at once found by drawing from C in the *force polygon* a parallel to this line to intersection with resultant. Thus *a* C (since we have taken *m n* parallel to S_1) is the force in *m n* and *a o*, 5 *a*, are the forces opposed to the resultant at *m* and *n*.

23. Influence of a Couple.—Among the forces in Fig. 12 there are two P_3 and P_3 which are equal, parallel and opposite, the direction of rotation being as indicated by the arrow. Examining the equilibrium polygon, we see that the influence of the couple is to *shift* S_1 *through a certain distance parallel to itself*, to S_4. Now suppose the forces composing the couple *were not given*, but the *value* of the couple known, from the direction of rotation and the area of the triangle A_2 P_2 P_3, which has its base equal to one of the forces and a height equal to their perpendicular distance. In this case the lines 1, 2 and S_2 in the *force polygon*, would disappear, but we can none the less find the point *d*, and from this point continue the polygon by drawing S_4 and S_5, and thus finding the same points *e* and 0′ as before. To do this we have simply to apply the principle deduced in Art. 21, that one couple *can be replaced by another provided the area of the triangle is constant.*

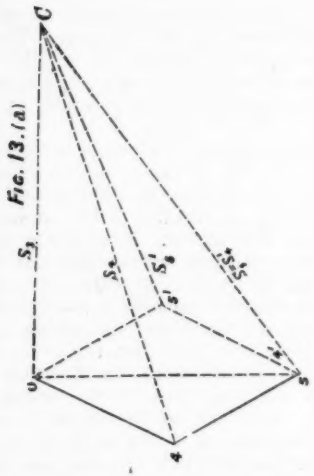
In the present case we must replace the given couple by another whose forces are S_1 and S_4, having the same direction of rotation.

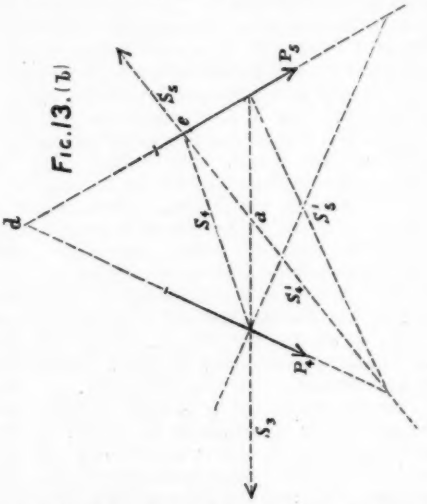
Lay off then from *a*, *a i* equal by scale to S_1 as given in the *force polygon*. Describe upon S_1 the triangle *a g h* equal to the given area A_2 P_2 P_3. Draw *g i*, and then through *h*, *h k* parallel to *g i*.

The point K is upon the line of direction of S_3, or in other words the area of the triangle i K a is equal to $a\ g\ b$. The proof is easy. The two triangles $i\ g\ h$ and $i\ g\ k$ are equal, since they have the same base $i\ g$, and height. But if from the triangle $a\ i\ g$ we subtract $i\ g\ h$, we obtain $a\ g\ h$. If from the *same* triangle $a\ i\ g$ we subtract $i\ g\ k$, which is *equal* to $i\ g\ h$, we obtain i K a. Equals subtracted from equals leave equals. Hence i K a is equal to $a\ g\ h$.

If then through K we draw a line parallel to S_3 and produce it to d, we have the same point as before, and this from d, can continue the polygon.

[*Note* that the direction of rotation





shows the side of S_1 upon which the point g must fall. S_1 acts away from a [from 1 to C in (a)] hence for rotation as shown by the arrow g must fall above S_1, and S_1 is shifted *upwards.*]

24. ORDER OF FORCES IMMATERIAL.—As in the case of a common point of application, so also here, the *order in which the forces are laid off is immaterial.* To prove this for two forces is sufficient, as by continued interchange of two and two, we can obtain any desired order.

Let the two forces be P_4 and P 5-1 existing either alone, or in combination with others preceding and following.

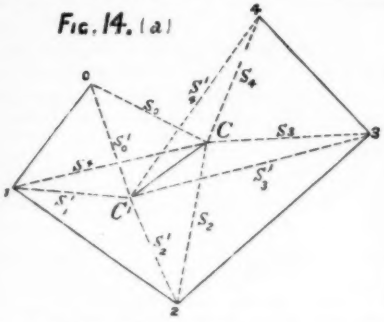
Taking the forces first in the order P_4 P_5, we have the *equilibrium polygon* S_3 S_4 S_5, giving the point a in the resultant. Taking them now in reverse order, P_5 P_4, we have the polygon S_3 S'_5 S'_4 giving the same point a in the resultant. The resultant in the force polygon (a), viz., 0 5, is of course unchanged in intensity and direction in either case. It is required to prove that in the second case the last string S'_4 is not only parallel to S_5 in the first, but *coincides with it.*

This is easy. The resultant of P_4 P_5 goes through a, the intersection of S_3 and S_5. The same resultant in the second case must also pass through the intersection of S_3 and S'_4. But S_3 is the same in position and direction in both cases. If the second point of intersection does not coincide with a, still it must lie somewhere upon S_3. Hence as the resultant must pass through both points, it must *coincide* with this last line; viz., S_3. But this is not possible, as the resultant must also pass through d, the point of intersection of the forces, or when these do not intersect must be parallel to them. As therefore S'_4 must be parallel to S_3 (shown by the force polygon), the intersections in each case must coincide, as also the lines S'_4, S_3 themselves, and the polygon from e on has the same course in either case.

25. POLE TAKEN UPON CLOSING LINE.—We have seen (Art. 20) that when any number of forces are in equilibrium *both* the force and equilibrium polygon must

close. There is one exception to this statement. Since the pole may be taken anywhere, suppose it taken somewhere

Fig. 14. (a)



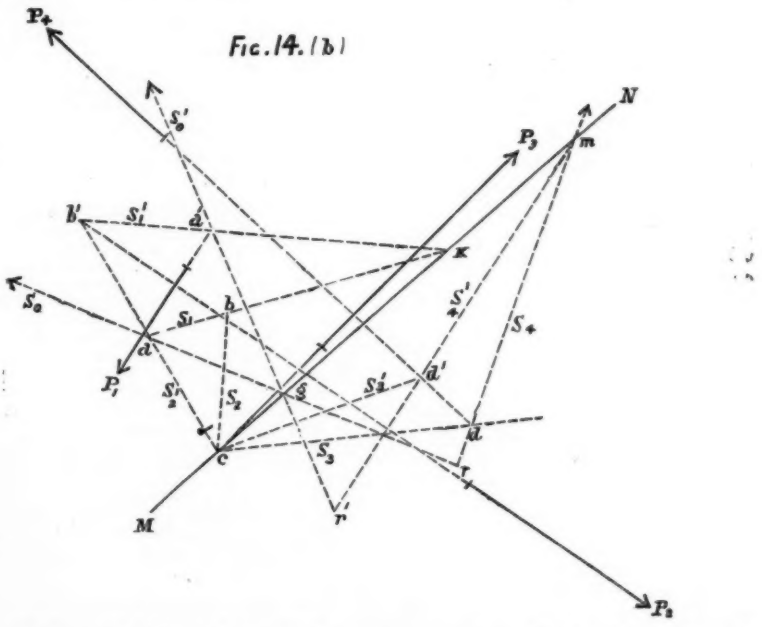
upon the line closing the force polygon. This line, as we know, is the resultant, and holds the other forces in equilibrium.

equilibrium. If the equilibrium polygon however does not close, the forces cannot be replaced by a single force but only by a couple. The forces of this couple act in the parallel end lines of the equilibrium polygon, and are given in intensity and direction of action by the line from the pole to the beginning of the force polygon [beginning and end coinciding.]

26. RELATION BETWEEN TWO EQUILIBRIUM POLYGONS WITH DIFFERENT POLES. —We may deduce an interesting relation between the two equilibrium polygons formed by choosing different poles, with the same forces and force polygon.

Thus with the forces P_1 P_2 P_3 P_4, we construct the force polygon Fig. 14 (*a*). Then choose a pole C and draw $S_{0,4}$, and thus obtain the corresponding equilibrium polygon S_0 *a b c d* S_4 Fig. 14 (*b*). Choose

Fig. 14. (b)



But now the equilibrium polygon evidently *will not close.* On the contrary the first and last strings will be parallel. This position of the pole should then be avoided. For any other position of the pole our rule holds good; viz.,

If the force polygon closes as also the equilibrium polygon, the forces are in

now a second pole C'. Draw $S'_{0,4}$ and construct the corresponding polygon S'_0 *a' b' c' d'* S'_4. In our figure *c* and *c'* fall accidentally nearly together.]

Join the two poles by a line C C'. Then —*any two corresponding strings of these two polygons intersect upon the same straight line M N parallel to C C'.* Thus

S_0 and S'_0 intersect at g, S'_1 and S_1 at K, S'_2 and S_2 at c, S'_3 and S_3 at c', S'_4 and S_4 at m—and *all* these points g, k, c, c' and m, lie in the same straight line M N parallel to the line C C′ connecting the poles.

The proof is as follows.* If we decompose P_1 into the components S_0 S_1 and S'_0 S'_1, these components are given in intensity and direction by the corresponding lines in the force polygon. If we take the two first as acting in opposite directions from the two last, they hold these last in equilibrium. The resultant therefore of any two as S_0 and S'_0 must be equal and opposed to that of the remaining two, S_1 and S'_1, and both resultants must lie in the same straight line. This straight line must evidently be the line $g\,k$ joining the intersections of S_0 S'_0 and S_1 S'_1. But from the force polygon we see at once that the resultant of S_0 and S'_0 is given in direction and intensity by C C′, and this is also the resultant of S_1 and S'_1. The line joining g and k must therefore be parallel to C C′. For the second force P_2 we can show similarly that the line joining k and c is parallel to C C′. But k is a common point of *both* lines—hence $g\,k$ and c lie in the same straight line parallel to C C′.

[NOTE. *The pure geometric proof is as follows: The two complete quadrilaterals* 0 1 C′ C *and* $g\,k\,a'\,a$ *have five pairs of corresponding sides parallel*, viz., 0 1 *and* $a\,a'$, 1 C′ *and* $a'\,k$, C 0 *and* $a\,g$, 0 C *and* $a'\,g$, 1 C *and* $a\,k$; *hence the sixth pair are also parallel*, viz., C C′ and $g\,k$. *In like manner for* 1 2 C C′ *and* $c\,k\,b'\,b$ *and so on.*]

We can make use of this principle in order from one given equilibrium polygon S_0 a b c d S_4 and pole to construct another, the direction of C C′ being known. For this purpose, having assumed the position of the first string S'_0 we draw through its intersection g with S_0 a line M N parallel to C C′. The next string must therefore pass through the intersection a' of S'_0 and P_1 and through the point k, of intersection of the second string of the first polygon and the line M N. It is therefore determined. The next side must pass through b' and c, and so on.

[*Note.* Observe that the intersections r and r' of the first and last lines of both polygons must lie in a straight line parallel to 0 4, the direction of the resultant.]

*Elemente der Graphischen Statik. Bauschinger. Pp. 18-19.

REPORTS OF ENGINEERING SOCIETIES.

THE American Society of Civil Engineers have devoted the time of their late meetings to the discussion of the City Rapid Transit Question. A complete list of their recent papers will be given in our next.

THE American Institute of Mining Engineers commenced their Winter Session on February 23.

AT a meeting of the American Iron and Steel Association, Mr. S. Z. Durfee read a valuable paper on the "Iron Trade and Transportation," an abstract of which we shall shortly reprint.

IRON AND STEEL NOTES.

SMOOTH AND BRILLIANT CASTINGS.—M. Collignon says that a saving of 80 per cent. is made by suppressing the sifted coal and charcoal used with green sand for small iron castings, by a careful mixture of one part of tar with twenty of green sand; the flashing by means of tar or resin is also suppressed by the same means. Castings produced from moulds with such a mixture are smooth and bright, because the tar prevents the metal adhering to the sand, and the formation of blisters. Such a mixture also aids greatly in the production of large castings, as the tar absorbs the humidity of the sand.—*Iron.*

IMPROVEMENTS IN PUDDLING.—M. Masian, of Louvroil, near Maubeuge, Nord, France, has patented in France and Belgium a new furnace. The form is nearly conical, the air being freely admitted through apertures made all along the face of the furnace at the height of the bars. The heat is made to concentrate itself in the sole of the furnace, accelerating the puddling. The puddler is exposed to much less heat than in the case of the square furnaces, and it is said to be able to make from eight to nine charges of good raw iron, No. 2, in twelve hours, with a consumption of 1,400 to 1,050 kilogs., an economy set down at 300 to 400 kilogs. of coal per ton of raw iron. The following are given as results of experience: With the Masian furnace, a ton of good No. 2 raw material was produced with 1,050 kilogs. of coal, the ordinary furnace requiring 1,300 kilogs. A ton of extra strong iron was produced in the new furnace with 1,252 kilogs. of coal, the old furnace consuming 1,502 kilogs.—*Iron.*

TEMPERING STEEL.—The Government of the United States has acquired, for the sum of 10,000 dollars, the following process, invented by MM. Garnant and Seigfield, for tempering steel: The steel, heated to a cherry red, is sprinkled with sea salt, and worked in this state until it has assumed nearly the form required, the chloride of sodium being renewed from time to time. For the latter is afterwards substituted a mixture of equal parts of chloride of sodium, sulphate of copper, sal-ammoniac, carbonate of soda, and a half-pint of saltpetre. The steel is again heated, and the hammer-

ing is continued until the steel becomes refined throughout its whole substance, and assumes the desired shape. It is then again brought slowly to a cherry-red heat, and plunged into a bath of 3.7 litres (3¼ quarts) of rain water, 42.4 grammes (1.484 oz.) of alum, the same quantity of carbonate of soda and sulphate of copper, 28.3 grammes (1 oz.) of saltpetre, and 169.8 grammes (5.843 oz.) of chloride of sodium.—*Iron.*

STEEL AND IRON MAKING.—M. Willans announces improvements in the following terms: 1. During reheating or fusion, in order to prevent burning, he injects over or under the metal oil, creosote, oxide of carbon, hydrogen gas, or other carburetted or hydrogenous substance, in order that the oxygen present may combine with it instead of oxidizing the metal. 2. Reheating or softening of cast iron or steel, when not placed in a cold state in the presence of substances producing oxygen, by bringing them in contact, when nearly at a red heat, with carbonic acid gas, produced from limestone or other carbonates; or, vapors containing oxygen gas, such as steam or nitrous acid, may be used for the purpose. 3. Steel tubes of good quality may be produced by the employment of only soft steel, which is easy to draw, by annealing them when half formed, in the presence of iron ore or other oxidizing agents. The same observations are applied to the making of tubes from a mixture of steel and cast-iron.—*Iron.*

RAILWAY NOTES.

PRESERVATION OF RAILWAY SLEEPERS.—A work has recently been published in France, entitled "A Treatise on the Preservation of Wood, Foods, and various Organized Matters," in which the author, M. Maxime Paulet, chemist, recommends for railway sleepers, pit props, and wood generally, the use of sulphate of copper and creosote.

M. Paulet says: So far as sulphate of copper is concerned, this salt is poisonous to the vegetable and animal parasites which appear at the beginning of all organic decomposition. The quantity of salts of copper should be excessive when the wood is intended to be immersed in water or buried in a moist soil, because the water dissolves this salt slowly; and since sea water enters into combination with it still more rapidly, it should be excluded from use for wood used in the sea. There is in wood impregnated with the salts of copper a portion of the sulphate closely united with the liqueous tissue and another portion in excess remaining free. This latter portion dissolves first, and, carried off by the exterior fluids, only retards the loss of the metallic salt combined with the wood; but this combination itself, although more stable, does not escape removal, being accelerated or retarded according to the rapidity and ease with which the dissolving liquid is renewed. On the contrary, the quantity of metallic salts should be diminished in wood intended for constructions in the open air, in order to prevent the mechanical effect of intra-vascular crystallizations.

As regards creosote oil, it is beyond doubt that the petroleum products containing phenic acid are preferable to the metallic salts for wood exposed to sea water, because naphthaline, and especially phenic acid, exercise an anti-septic action, coagulate the albumen, and thus obstruct the circulation of the sap or blood of parasites. The volatility and the solubility of these preservative agents would render their antiseptic action temporary only, if the more fixed and thicker oils which accompany them did not enclose and retain the preceding substances, at the same time obstructing all the pores of the wood, and rendering difficult the access of dissolving liquids and destructive gases. On the other hand, grave objections have been raised from a practical point of view, either because of the restricted production of these oils, which is not sufficient for a general use of them, or because the wood thus impregnated offers greater danger from fire, this wood once on fire being unextinguishable; that, on the contrary, sulphate of copper, like all the metallic salts, renders the wood uninflammable.

On the subject of the preservation of wood the *Polytechnisches Centralblatt* has lately remarked that in 1862 Messrs. J. and G. Leuchs advised the boiling of railroad ties in paraffine, or coating them with this substance; but this operation did not seem practicable to Mr. Hock. In order to effect impregnation it is necessary to fuse the paraffine, and vapor of petroleum seemed to him the dissolvent best suited for this purpose. The ties are introduced into an iron cylinder or reservoir, heated on the outside by a steam jacket. The wood, already as dry as possible, is raised to the highest degree of desiccation by the introduction of steam into the jacket, and when no more vapor escapes from it the solution of paraffine is introduced into the cylinder by means of a tube and compressed air. This cylinder has a refrigerating coil which discharges into a closed receiver. Then steam is let into the jacket again. The liquid waters boiling, and the vapor of petroleum gas not being able to escape, the pressure inside the cylinder rises, and is permitted to reach 75 to 100 lbs. per square inch; at this pressure the wood is completely impregnated with the liquid. When this action has been prolonged sufficiently, the heating is stopped and the operator waits until the pressure has fallen to a mininum, and the excess of paraffine is drawn off into the reservoir. Now, in order to collect also the dissolvent absorbed by the wood, it is again heated. When the remainder of the vapor of petroleum has been dissolved, air is blown into the cylinder in order to drive out the gases which might incommode the workmen who take out the wood.

The paraffine remains distributed minutely within the wood between the ligneous fibres, envelopes them, on melting, with a thin coating, and at the same time fills the pores and the cellular intervals. The wood is then guaranteed forever against moisture, while the dissolving of sulphate of copper, chloride of zinc, coal oil, etc., which have been recommended, are dissolved and carried off by water. Nails do not rust as in wood impregnated with metallic salts, and fragments of the preserved wood keep their value as fuel, while those of sulphated or zincked wood burn with difficulty.

FATTY MATTER IN FEED-WATER OF BOILERS.—It is known that a quantity of fatty matter in the feed-water of a boiler causes a deposit which is not wet by water, and that this may lead to destruction of the boiler, inasmuch as the part of boiler side under the incrustation becomes more heated than other parts, and is apt to occasion rupture. A case of this kind, observed by M.

Birnbaum, of Carlsruhe, has formed the subject of an investigation which he describes in a recent number of Dingler's *Polytechnisches Journal*.

The boiler in question had become leaky about two months after working had commenced, and most likely from a cause like that indicated, the incrusted boiler plates getting heated, and being bellied out by the steam pressure; when the boiler cooled, the metal sought to right itself, and thereby a force was developed sufficient to tear the rivet holes.

In the boiler there was found, besides a paper-thick coating of the usual deposit over the whole surface that was under water, a layer (from 2 to 3 mm. thick), of pulverulent matter, on the foremost half of the boiler bottom, which was a little inclined towards the fireplace. This powder was found very difficult to wet with water. Analysis showed that the incrustation contained a soap not soluble in water; there was at least six per cent. fatty acid present in the form of an insoluble soap. This fatty acid must have been neutralized by a certain quantity of lime or magnesia; and, to determine this, a quantitative analysis of the deposit was made. The result was: Matter insoluble in muriatic acid (mud, sand), 16.83 per cent.; oxide of iron, 10.68; lime, 29.28; magnesia, 9.01; carbonic acid, 21.78; organic matter, 9.47; water, 2.77; total, 99.82 per cent. There was also present a small quantity of sulphuric acid which could not be quantitatively determined. If we suppose the whole of the carbonic acid combined with lime, this will take 27.72 per cent of lime, so that 1.56 per cent. lime and 9.01 per cent. magnesia remain available for neutralization of the fatty acid (which is included in the organic matter in the above analysis). With the proviso that the fatty acid was mainly oelic acid, the 1.56 per cent. lime would more than suffice to neutralize the acid; a portion of the alkaline earths must thus have been free, perhaps in the form of a basic carbonate, in the deposit. It appeared, at all events, from this analysis that the powder contained at least 7 to 8 per cent. of an insoluble soap.

A further point to determine was whence the fat of this soap had come into the boiler. On examination it appeared that the spring water used for feeding the boiler was peculiarly adapted for this. The water, however, was previously heated in a heater, by waste steam entering it directly from the engine. Through the introduction of this steam the water was diluted, then distilled water was added, so that the water from the heater might give less deposit than the spring water. But in addition to the pure water condensed from the steam, other matters were introduced in the heater, which conduced to increase the precipitation of deposit. These were partly of an inorganic, partly of an organic nature. Among the inorganic matters must especially be mentioned hydrated oxide of iron. It could not but be that through action of air and carbonic acid of the spring water, the iron sides of the heater should have been covered with rust, which should afterwards be dissolved and transferred to the water. The iron rust was, however, only suspended in the water; filtered water of the heater contained no iron. The quantity of organic matters introduced into the water by the steam was not insignificant. These also are not soluble in water; filtered water of the heater contained a less quantity of organic matter than the spring water. The water out of the heater was directly examined for fat and soap, and out of 6 litres water .017 g. isolated fatty acid was obtained. With a still larger quantity the filtered water was quite free from soap, while the unfiltered showed a quantity of insoluble soap. Thus it appeared that the spring water, through contact with steam, took up fatty matter in the heater; this fat formed a soap insoluble in water, suspended in water along with hydrated oxide of iron. Volatile fatty acids—*e. g.*, butyric acid—which, in similar cases, have sometimes been found in feed water, were not observed by M. Birnbaum.

It follows as a practical result of this investigation, that the water in the heater should not be brought into direct contact with the waste steam. It is more rational to send the steam through pipes, over which the feed-water is made to pass. If the steam be sent direct into the water in the heater, the danger arising from presence of fatty matter may be so far diminished by filtration of the feed-water.

ENGINEERING STRUCTURES.

THE CHANNEL TUNNEL.—The project of connecting England and France by a sub-marine tunnel is said to have been the subject of conversation between the Lord Mayor and the Minister of Public Works in Paris, and an arrangement is reported by the *Daily News* to have been come to between the governments of England and France, sanctioning preliminary experiments.

In 1872, the Channel Tunnel Company was incorporated; and Sir John Hawkshaw, Mr. James Brunlees, and M. Thomé de Gamond were appointed the engineers of the undertaking. Mr. W. Low, a gentleman much interested in the scheme previous to the formation of the company, has, we understand, now ceased to have any connection with it in an official capacity. The assent in principle of the governments of England and France has been obtained; but until the time arrives for constructing junctions with the railways terminating at Dover there will be no occasion to apply to Parliament. On the English coast, St. Margaret's Bay, a depression in the chalk cliffs, about four miles east of Dover, has been selected as the point of departure; and on the French side, a spot about midway between Calais and the village of Sangatte, has been fixed upon. By adopting this line, it appears from observations which have been made by Sir John Hawkshaw, that the tunnel can be almost wholly excavated in the lower bed of homogeneous chalk; and this stratum is upwards of 500 feet deep on each shore from high-water mark. It is believed, on apparently good grounds, that the chalk is continuous, and that it stretches beneath the sea uninterruptedly across the Straits. The maximum depth of water on the line of the proposed tunnel nowhere exceeds 180 feet below high-water mark, the water being deepest in the centre, and gradually diminishing in depth towards the sides. The tunnel itself would be placed by the engineers at such a level that the depth of strata over it would never be less than 200 feet; and this depth, which is amply sufficient for security, would permit the railway approaches to be formed with tolerably easy gradients. It has been ascertained by actual experiment that, provided the chalk be solid, the water will not permeate it; and it has also been shown on more than one occasion that comparatively little subterranean water exists in that formation. But the best possibility

of tunnelling beneath the sea level is to be found at Brighton. Sir John Hawkshaw has there completed a tunnel 5½ miles in length along the sea shore, and in close proximity to the margin of the sea. This tunnel is wholly in the upper chalk, where the material is not very compact; and it is 12 feet at one end, and 20 feet at the other end below high-water mark. Considerable quantities of water, chiefly fresh, were encountered in the progress of the work, and as much as 10,000 gals. per minute had sometimes to be pumped out; but the works were not prevented from proceeding. As pumping power ten times the magnitude of that employed at Brighton could, if necessary, be applied, the entry of small quantities of water during the construction of the Channel tunnel would not be in the least dangerous. Nothing, probably, could hinder the completion of the work but the existence of open, unfilled fissures reaching from the sea to a depth of at least 200 feet. It is believed that such fissures, if at any time existing, will be found to have been filled up in the lapse of ages.

With regard to the means by which it is proposed to execute the work, we should mention that tunnelling machinery has lately been invented by Mr. Dickenson Brunton (see *Iron*, Vol. III., p. 364, where the Channel tunnel is fully discussed) which has been practically and successfully tried in the lower chalk. The machine works like an auger, and the debris excavated falls upon an endless band which carries it to the wagons in the rear. By this means a driftway of 7 feet in diameter can be advanced at the rate of from a yard to a yard and a quarter per hour, and at this rate it would only require two years to pierce a way of 7 or 9 feet in diameter from one side of the Channel to the other, a machine being worked from each side. The engineers' estimates of time and cost for the preliminary works are four years and £1,600,000 respectively; but experienced contractors think that only half the time and money would be required. It has also been computed that after the driftway is finished, four years' time and £4,000,000 would complete the entire work. We are assured that the ventilation of the tunnel, both before and after completion, would present no great difficulties. As the work advanced, pneumatic tubes might be laid down, which would not only aid ventilation, but which would also carry in and bring out the workmen, and remove the excavated chalk. When the tunnel is finished, it is expected that engines of 150 horse-power in the aggregate will provide sufficient permanent ventilation. The railway once completed, we suppose that few people will be found to deny its utility.

Proposed Mont Blanc Tunnel.—It seems that the French Government is not now disposed to subsidize the railway which was formerly one of the cherished projects of the Empire, and was distinguished by the name of *La Ligne d'Italie*. This line was to have been carried through the Simplon, and some considerable progress had already been made with it on both sides of the Alps when the Franco-German war caused an interruption of the works, the result of which was that the Swiss Government declared the concession which had been made to a French company to be forfeited, and then took possession of the plans and material, as well as of the line itself. Against this act the French Government remonstrated, but as the line nowhere touches French territory, it does not now seem likely to receive any pecuniary assistance from that quarter. The failure of this enterprise has given rise to a project for constructing a railway through the Alps which shall connect the frontiers of France, Italy, and Switzerland; and the French journal, *Le Constructeur*, gives the details of a survey lately made with this view by M. Ernest Stamm, a French engineer, assisted by Signor Léon Maimeri, who, after carefully inspecting and surveying the district for two consecutive years, ascertained that a section of Mont Blanc taken at an altitude of 1,300 metres, presents a base of only 11½ kilometres, and that a line of railway starting from Chamounix and tapping the mountain at or near Les Houches, would not present engineering difficulties so great as have already been surmounted at Mont Cenis, or are now being overcome at St. Gothard, and it would, moreover, prove much more advantageous to France as a commercial line than that by the Simplon, as well as offer the greatest attraction to tourists.

ORDNANCE AND NAVAL.

The Fog Gun.—For some time past endeavors have been made to secure for coast-signal purposes something more suited to the duty than the 18-pounder cast-iron gun now used. Major Maitland, R. A., of the Royal Gun Factory, has designed a species of revolving gun which will no doubt answer the purpose admirably. But in order to determine the best material and form of muzzle for the new fog gun, four models, each 2 feet long and capable of containing a cartridge consisting of from four to five ounces of powder, were constructed upon the following different plans, to be tested from the summit of the proof butts in the Plumstead marshes, at various respective distances: A cast-iron gun with a plain muzzle; a cast-iron gun with a conical mouth; a cast-iron gun with a parabolic mouth; and a bronze gun with a parabolic mouth. The object of trying both conical and parabolic mouths was to arrive at a decision in regard to the question which has always been pending among manufacturers of speaking-trumpets, as to which is the best shape for transmitting sound. Some assert that the form of the instrument should be a truncated cone; others, that it should be a truncated parabolic canoid, the mouthpiece occupying the focus. Either form would, in a greater or less degree, confine the undulations of sound (which would otherwise disperse themselves in all directions) and cause them to take a direction parallel to the axis. Hence the application of one or the other of them. On the occasion of the recent experiments the four models were placed in a row upon the summit of the butts, with their muzzles pointing towards Shooter's Hill. The weather was cold and clear. The observers stationed themselves at various distances in front of the row of guns, from 100 to 3,000 hundred yards, moving forward to a greater distance each time that the whole series of four guns was fired. They were ignorant of the order in which the guns were fired, that being purposely left in the hands of the proof master, so it was impossible for their opinions to be prejudiced. It was decided that the volume of sound emitted by each discharge should be presented as nearly as possible in figures, No. 1 being the "highest" figure of merit, and No. 5 the lowest. The following results were obtained: Adding together the respective figures of merit of each gun at eight several distances from 100 to

3,000 yards, it was found that the cast-iron gun with the conical mouth gave a total of 10, or in other words took the first place as regards the volume of sound produced at all ranges; the cast-iron gun with the parabolic mouth a total of 21, thus taking the second place; the bronze gun with the parabolic mouth a total of 22½, or taking the third place; while the cast-iron gun with the plain or straight mouth gave 26½, the lowest value of all four. At a distance of a thousand yards only, the bronze gun with the parabolic mouth took the second place. This was probably due to the superior ringing qualities of the metal, which would be observed at such a short range. Further experiments were then made by observers stationed about two miles off upon Shooter's Hill. The figures of merit under these circumstances for the several guns were as follows: Out of six observations, 6 for the cast-iron cone, 12½ for the cast-iron parabola, 19 for the bronze parabola, and 22½ for the cast-iron plain mouth. Thus we see that the great increase of distances is very unfavorable to the bronze model, and that the plain muzzled one is out of the field altogether.

During the above-mentioned experiments trials were made with gun-cotton, in order to see whether the sound of its report on explosion would reach to any great distance. Masses consisting of about ten ounces were detonated in the open air upon the butts. The noise made considerably exceeded that of the guns. It must be remembered, at the same time, that the proportion of powder in the gun-cartridges bore no analogy to the quantity of gun-cotton detonated. The result of the trials was, however, considered so satisfactory that a parabolic reflector is being constructed in which it is intended to explode pieces of gun-cotton.—*The Engineer.*

BOOK NOTICES

A Practical Treatise on the Gases Met with in Coal Mines. By J. J. Atkinson. New York: D. Van Nostrand. Price 50c.

This is No. 13 of Van Nostrand's Science Series, and is reprinted from the Magazine.

The original essay was prepared for the Manchester Geological Society (Eng.), and was published there to meet a wide demand.

The author, now deceased, was then Government Inspector of Mines.

Ceramic Art: A Report on Pottery, Porcelain, Tiles, Terra Cotta, and Brick. By Wm. P. Blake. New York: D. Van Nostrand. $2.00.

This is a volume of 140 pages. It is from the Reports of the Massachusetts Commission to Vienna.

The separate sections are devoted respectively to: General Survey; Porcelain and Faience; Floor, Wall, and Ornamental Tiles; Terra Cotta and Brick; Materials for Pottery.

A chart exhibiting the Monograms on Porcelain and Faience closes the report.

Many good illustrations are scattered through the text.

Chemical Examination of Alcoholic Liquors. By Albert B. Prescott, M. D. New York: D. Van Nostrand. Price $1.50.

The judgment of those whose opinions are of most value, has already been expressed in regard to the merits of this new work from the accomplished author of "Proximate Organic Analysis." The opinion was based upon the conspicuous merits of the above-mentioned work, and was unqualifiedly favorable.

The present work is designed as a manual of the constituents of the distilled spirits and fermented liquors of commerce, and their qualitative and quantitative determination.

"It has been shaped by the design, firstly as a necessary basis for analysis, to place in outline the chemistry of alcoholic liquors, including their current impurities and adulterations, in such terms as to be understood by persons having only an ordinary acquaintance with chemical science. Secondly, to furnish directions, so far as possible, for an efficient chemical examination, not more elaborate than required for commercial, hygienic, and legal purposes, and containing all details except such as are found in the first books of chemical analysis."

The book is nearly the size of "Proximate Analysis," and will supply a want more widely felt than that which rendered the first work so acceptable.

The Earth a Great Magnet. By A. M. Mayer, Ph. D. New York: D. Van Nostrand. 50c.

This is only an old acquaintance in a more fitting dress. In flexible cloth cover and with wider margins to the pages, it presents a far more satisfactory appearance than it formerly did.

The demand for this excellent essay is quite steady, and deservedly so, for from no other source can the student obtain so much accurate knowledge of terrestrial magnetism in so compact and readable shape. The change in outside fittings above referred to is coincident with the recent change in ownership of the "University Series" to which the book belongs.

Scientific Addresses. By John Tyndall, L.L.D., F. R. S. New York: D. Van Nostrand. 50c.

This formed No. 5 of the University Series, formerly published by C. C. Chatfield & Co. It now appears in neat flexible cloth cover, and is in every sense in appropriate dress.

Professional Papers of the Corps of Royal Engineers. Woolwich: Jackson & Sons. Price $8. For sale by D. Van Nostrand.

Volume 22 of the new series is at hand, and as usual the volume contains much that interests the profession at large.

Among other papers (there are thirteen in all) we notice: Our present Knowledge of Building Materials, and how to improve it; Experiments on the holding power of Earth, and the strength of Materials; The recent History of Explosive Agents; Notes on Portland Cement, and the Description of the Operation of Straightening a Brick Chimney Shaft at Woolwich.

The illustrations are for the most part excellent. A few poor heliotypes do not essentially mar the appearance of the book.

Principles of Metal Mining. By J. H. Collins, F. G. S. Lond. and Glasgow: Wm. Collins, Sons & Co. For sale by D. Van Nostrand. 75c.

This is another of the Collins Series, and affords an outline rudimentary in character of methods and tools employed in mining. It is rather meagre as a source of information to a student, but perhaps is sufficient for a general reader who is short of time.

ELEMENTS OF MAGNETISM AND ELECTRICITY. By JOHN ANGELL. London: Wm. Collins, Sons & Co. For sale by D. Van Nostrand. Price 75c.

This is an important addition to Collins's Elementary Science Series. It is compact, well illustrated, and affords valuable hints to experimenters as to construction and use of apparatus. It is illustrated with 120 wood cuts.

THE MICROSCOPE AND ITS REVELATIONS. By WM. B. CARPENTER, M. D. Fifth Edition. For sale by D. Van Nostrand. Price $5.50.

This is a new edition of an old and well-known book. Its reputation for general excellence is as wide as the use of the microscope among English readers. The present edition contains 25 plates and 449 wood engravings.

NOTES AND QUERIES ON ANTHROPOLOGY. By a Committee of the British Association. London: Edward Stanford.

This little work is designed as a guide to travellers and residents in uncivilized lands, pointing the way by which their observations may advance the science of Anthropology. There are one hundred sections or chapters, by a large number of scientists; each section giving a complete list of questions on a special subject, the answers to which are solicited from any who hold intercourse with barbarous peoples in any part of the globe.

To the general reader the book is of value, inasmuch as it indicates the line of study of the workers in this field.

THE ORIGIN OF CREATION, OR THE SCIENCE OF MATTER AND FORCE. By T. R. FRASER, M. D., and ANDREW DEWAR. London: Longmans, Green & Dyer. For sale by D. Van Nostrand. $4.

The title of this work is, to say the least, ambitious, and the first lines of the preface are not inconsistent with the character assumed by the title page. They run thus: "Unknown to the world of science, we present ourselves as advocates of the vast undertaking, which is we expect to revolutionize the whole theory of Natural Science taught and believed in at the present day, and to—" etc., etc. This is sufficient, we trust, to satisfy our readers that this span of authors make in no place an obtrusive exhibition of modesty. There are 234 pages of the effusion, but in brief scanning we could not find one of information.

AIR AS FUEL. By OWEN C. D. ROSS, C. E. London: E. & F. N. Spon. 1874. For sale by D. Van Nostrand. Price $1.50.

This is a compact and well arranged little work, not too diffuse, but containing much useful information. Though devoted to the support of what the majority would designate as a crotchet, viz., the sufficiency of oil-saturated air as a substitute for coal and coal-gas, it is far from devoid of value as a contribution to the already voluminous literature of fuel. It is to be regretted, however, that the author should not have given a sketch of the history of the many attempts that have been made to introduce the use of oil-gas, some of which have met with partial success. An analysis of the causes of failure would be highly instructive; and, till this has been done, the career of the Air Gas and the New Gas Companies, with other kindred undertakings, has been such as to discourage further attempts in the same direction, till there is some assurance of a palpable advance having been attained on the *modus operandi* hitherto adopted. The recent unprecedented fall in the price of petroleum, occurring simultaneously with the development of the oil-grounds of Asia, is, as Mr. Ross rightly points out, an important element in the matter. The latter half of the book, treating of carburetted air as an illuminating gas, though exhibiting somewhat of the sanguine spirit of the inventor, states fairly the grounds on which an opinion as to the chance of success of the new proposal may be formed.—*Iron.*

CATECHISM OF THE LOCOMOTIVE. By M. N. FORNEY, Mechanical Engineer. New York: Railroad Gazette. For sale by D. Van Nostrand. $2.50.

This book, which has been published in weekly parts in the *Railroad Gazette* during the first nine months of 1874, is now ready in book form. It treats, in 550 questions and answers, of the following subjects:

Part 1. The Steam Engine.
2. The Forces of Air and Steam.
3. On Work, Energy, and the Mechanical Equivalent of Heat.
4. The Slide-Valve.
5. The Expansion of Steam.
6. General Description of a Locomotive Engine.
7. The Locomotive Boiler.
8. The Boiler Attachments.
9. The Throttle-Valve and Steam Pipes.
10. The Cylinders, Pistons, Guide-Rods, and Connecting Rods.
11. The Valve-Gear.
12. The Running-Gear.
13. Adhesion and Traction.
14. Internal Disturbing Forces in the Locomotive.
15. Miscellaneous.
16. Screw Threads, Bolts, and Nuts.
17. Tenders.
18. Friction and Lubrication.
19. Combustion.
20. The Resistance of Trains.
21. Proportions of Locomotives.
22. Different Kinds of Locomotives.
23. Continuous Train Brakes.
24. Performance and cost of Operating Locomotives.
25. Water-Tanks and Turn-Tables.
26. Inspection of Locomotives.
27. Running Locomotives.
28. Accidents to Locomotives.
29. Accidents and Injuries to Persons.
30. Responsibility and Qualification of Locomotive Runners.

The book is illustrated with 250 wood engravings, nearly all from original drawings.

The talented editor of the *Gazette* has exhibited in this work remarkable power as an instructor. The expositions of principles are clear, concise, and yet full. The book has no competitor in the market, and we trust it will be found to be indispensable to every student of Mechanical Engineering who can read English.

A MANUAL OF TELEGRAPH CONSTRUCTION. By JOHN CHRISTIE DOUGLAS. London: Charles Griffin & Co. For sale by D. Van Nostrand. $7.50.

The telegraph engineer must be familiar to some extent with the practical duties for which the civil engineer is specially prepared. He must be familiar with the principles of framing, of determin-

ing the strains in struts and ties of complex trusses; with the general principles governing earthworks, whether in relation to retaining walls or foundations, and also with the methods of constructing good masonry. To be sure he is rarely called upon to apply these principles on an extensive scale, but a due regard to economy and durability requires a sound knowledge of the rudiments at least of these departments of civil engineering.

The author of the work before us begins his treatise with a comprehensive outline of Physics and Mechanics. The work is carefully done, and is worthy the attention of writers of more pretentious works of engineering.

The remaining sections treat in minute detail of the duties of the line builder, and the devices by which he overcomes obstacles of all possible kinds. Everything which is likely to demand the engineer's attention in his field work seems to have been considered, even to camp equipage and choice of camping ground.

The work contains 420 closely printed pages, and is abundantly illustrated.

ECONOMIC GEOLOGY; OR, GEOLOGY IN ITS RELATIONS TO THE ARTS AND MANUFACTURES. BY DAVID PAGE, L. L. D., F. G. S., &c. William Blackwood & Sons. Price $3.75.

It is to the credit of Mr. Page that in the volume which has given rise to these remarks, or rather in those chapters which refer to architecture and engineering, he has not followed the method of treatment usual with writers on geology, but has regarded stones from a practical standpoint. He has brought together a large quantity of information on the ordinary building stones, and on stones for decoration and sculpture, and for limes, cements, concretes, etc. The employment of stone in road-making, construction of railways, canals, docks, etc., is also treated. By confining himself principally to the stone found in England, and by good arrangement and concise expression, the chapters on architecture and engineering contain the pith of all that is known on the subject. The book, however, is intended for a wide circle of readers, as it treats in a similar style of geology in its relations to agriculture, land valuation, mining, pottery, medicine, metallurgy, etc. It can be recommended as a companion to all treatises on geology. A geological map, on a small scale, but comprehensive enough, accompanies the volume.

MISCELLANEOUS.

A NEW ENAMELLING PROCESS.—The uses of enamelled plates during recent years have widely extended, and with the gradually accumulating improvements in the process of enamelling, will doubtless continue to extend. Their durability recommends them for all purposes where permanency is a desideratum, such as advertisements on walls, street names, and a hundred and one appliances in civilized life. For some years now a company has been working a patented process of enamelling plates of metal—sheet iron or copper generally—with lettering or designs suitable for various purposes, and for some time efforts have been made to reduce the cost of the process or to invent a new and cheaper one. If we may believe the patentee, Mr. J. H. Robinson, of Liverpool, has recently invented a process which is not only cheaper, but in which the resulting product is free from those specks of dirt which seem inseparable from the present methods of manufacture. The new process yields enamel of sufficient purity for dials and similar work, and is not so expensive as to virtually prohibit its use for ordinary purposes, such as name plates, notice boards, and wall advertisements. Thin sheet-iron is first cut and stamped to the desired shape, the edges of the plate being turned up slightly in the usual way so as to form a shallow tray, the edge serving to hold the enamel in position during the preliminary stages of the process. The plate is then to be made chemically clean by any of the ordinary processes of pickling and scouring. The ingredients of the enamel should be taken in the following proportions, but in some cases, or for certain purposes, they may be slightly varied: White lead, 12 oz.; arsenic, 2½ oz.; flint glass, 8 oz.; saltpetre, 3 oz.; borax, 6¾ oz.; and ground flint, 2 oz. These are to be powdered and mixed thoroughly, placed in the crucible and fused; but before they are cooled they must be plunged into cold water, which has the effect of rendering the mass very brittle. The cakes of fused enamel are then pounded to about the fineness of coarse sand, washed and dried. The powder is then ready for use. The plates of sheet iron having been well cleansed and thoroughly dried, are sprinkled over with sufficient enamel powder to make the coating of the desired thickness, and are then placed in a muffle, the turned up edges retaining the swelling enamel in position. Lettering or designs can be produced on the surface by the ordinary means; but if it is desired to put them on when the enamelled plate is cold, they are first received on paper, an impression being taken on soft black enamel from the engraved plate, and subsequently transferred, the article being again placed on the muffle to fuse the enamel of the design or letters. The inventor claims that the iron back is more durable than copper, and it certainly is cheaper. Variations in the color of the enamel can of course be obtained by the addition of various salts and earths, such as those of cobalt, peroxide of manganese, protoxide of iron, etc., and similar diversity of color can be introduced into the design or the letters.—*Eng. Mech.*

THE subject of underground temperatures at the British Association was treated in a report by Professor Everett, in which it is pointed out that the average result thus far is that the temperature increased at the rate of 1 deg. Fahr. in every 50 feet or 60 feet in depth. A very valuable set of observations has been received from a mine 1,900 feet deep in Prague, Bohemia. The depths and corresponding temperatures are as follows:

Feet.	Deg. Fahr.	Feet.	Deg. Fahr.
68	47.9	1,290	58.3
299	48.8	1,414	59.4
621	50.7	1,652	61.2
939	57.8	1,900	61.4

IRON or steel wire which has been acted on superficially by sulphuric acid is usually found to be altered in its properties. Its weight is increased, its tenacity is injured, so that originally soft and flexible, it easily breaks; and when a freshly-broken end is moistened by the tongue, it effervesces as if acted on by a mineral acid. These effects after a time disappear. Professor Osborne Reynolds, of Manchester, has ascertained that they are owing to the absorption of hydrogen generated during the chemical reaction which takes place when the wire is immersed in the acid.

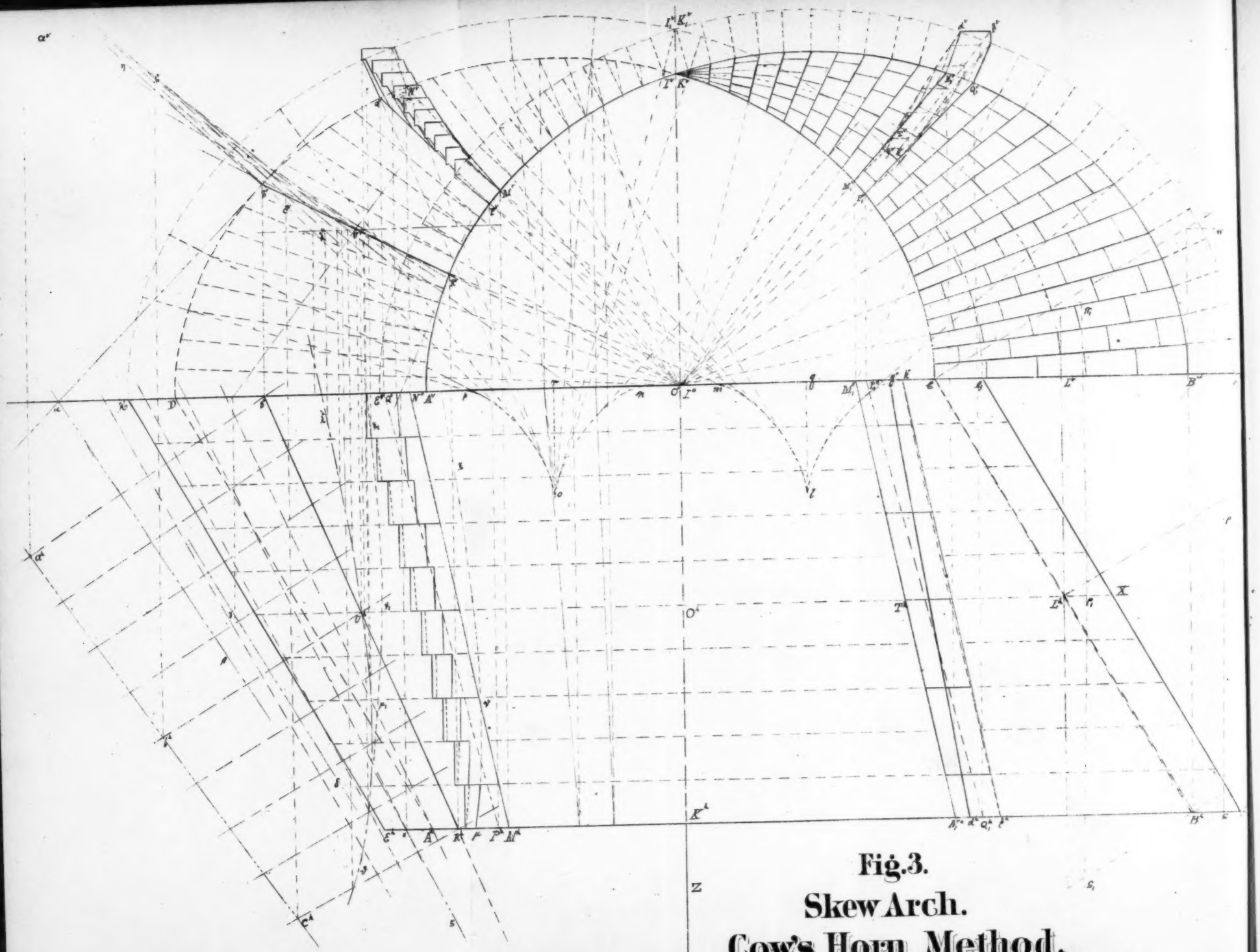


Fig.3.

Skew Arch.

Cow's Horn Method.